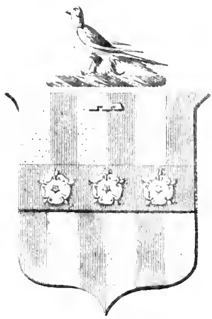

Joseph · Martineau

THE BRIDGEWATER TREATISES

ON THE POWER WISDOM AND GOODNESS OF GOD

AS MANIFESTED IN THE CREATION

TREATISE IV

THE HAND ITS MECHANISM AND VITAL ENDOWMENTS

AS EVINCING DESIGN

BY SIR CHARLES BELL K.G.H.

F. R. S. L. & E.

[FOURTH EDITION]

THE HAND

ITS MECHANISM AND VITAL ENDOWMENTS

AS EVINCING DESIGN

BY

SIR CHARLES BELL K.G.H.

F.R.S. L. & E.

PROFESSOR OF SURGERY IN THE UNIVERSITY OF EDINBURGH

ALDI DISCIP. ANGLVS

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WILLIAM PICKERING

1837

C. WHITTINGHAM, TOOKS COURT, CHANCERY LANE.

NOTICE.

The series of Treatises, of which the present is one, is published under the following circumstances:

The Right Honourable and Reverend Francis Henry, Earl of Bridgewater, died in the month of February, 1829; and by his last Will and Testament, bearing date the 25th of February, 1825, he directed certain Trustees therein named to invest in the public funds the sum of Eight thousand pounds sterling; this sum, with the accruing dividends thereon, to be held at the disposal of the President, for the time being, of the Royal Society of London, to be paid to the person or persons nominated by him. The Testator further directed, that the person or persons selected by the said President should be appointed to write, print, and publish one thousand copies of a work *On the Power, Wisdom, and Goodness of God, as manifested in the Creation; illustrating such work by all reasonable arguments, as for instance the variety and formation of God's creatures in the animal, vegetable, and mineral kingdoms; the effect of digestion, and thereby of conversion; the construction of the hand of man, and an infinite variety of other arguments; as also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature.* He desired, moreover, that the profits arising from the sale of the works so published should be paid to the authors of the works.

The late President of the Royal Society, Davies Gilbert, Esq. requested the assistance of his Grace the Archbishop of Canterbury and of the Bishop of London, in determining upon the best mode of carrying into effect the intentions of the Testator. Acting with their advice, and with the concurrence of a nobleman immediately connected with the deceased, Mr. Davies Gilbert appointed the following eight gentlemen to write separate Treatises on the different branches of the subject as here stated:

THE REV. THOMAS CHALMERS, D.D.

PROFESSOR OF DIVINITY IN THE UNIVERSITY OF EDINBURGH.

ON THE POWER, WISDOM, AND GOODNESS OF GOD AS MANIFESTED IN THE ADAPTATION OF EXTERNAL NATURE TO THE MORAL AND INTELLECTUAL CONSTITUTION OF MAN.

JOHN KIDD, M.D. F.R.S.

REGIUS PROFESSOR OF MEDICINE IN THE UNIVERSITY OF OXFORD.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE PHYSICAL CONDITION OF MAN.

THE REV. WILLIAM WHEWELL, M.A. F.R.S.

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

ASTRONOMY AND GENERAL PHYSICS CONSIDERED WITH REFERENCE TO NATURAL THEOLOGY.

SIR CHARLES BELL, K.G.H. F.R.S. L.&E.

PROFESSOR OF SURGERY IN THE UNIVERSITY OF EDINBURGH.

THE HAND: ITS MECHANISM AND VITAL ENDOWMENTS AS EVINCING DESIGN.

PETER MARK ROGET, M.D.

FELLOW OF AND SECRETARY TO THE ROYAL SOCIETY.

ON ANIMAL AND VEGETABLE PHYSIOLOGY.

THE REV. WILLIAM BUCKLAND, D.D. F.R.S.

CANON OF CHRIST CHURCH, AND PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD.

ON GEOLOGY AND MINERALOGY.

THE REV. WILLIAM KIRBY, M.A. F.R.S.

ON THE HISTORY, HABITS, AND INSTINCTS OF ANIMALS.

WILLIAM PROUT, M.D. F.R.S.

CHEMISTRY, METEOROLOGY, AND THE FUNCTION OF DIGESTION, CONSIDERED WITH REFERENCE TO NATURAL THEOLOGY.

His Royal Highness the Duke of Sussex, President of the Royal Society, having desired that no unnecessary delay should take place in the publication of the above mentioned treatises, they will appear at short intervals, as they are ready for publication.

PREFACE.

When one has to maintain an argument, he will be listened to more willingly if he is known to be unbiassed, and to express his natural sentiments. The reflections contained in these pages have not been suggested by the occasion of the Bridgewater Treatises, but arose, long ago, in a course of study directed to other objects. An anatomical teacher, himself aware of the higher bearings of his science, can hardly neglect the opportunity which the demonstrations before him afford, of making an impression upon the minds of those young men who, for the most part, receive the elements of their professional education from him; and he is naturally led to indulge in such trains of reflection as will be found in this essay.

So far back as the year 1813, the late excellent vicar of Kensington, Mr. Rennell, attended the author's lectures, and found him engaged in maintaining the principles of the English school of Physiology, and in exposing the futility of the opinions of those French philosophers and physiologists, who represented life as the mere physical result

of certain combinations and actions of parts by them termed Organization.

That gentleman thought the subject admitted of an argument which it became him to use, in his office of "Christian Advocate."* This will show the reader that the sentiments and the views, which a sense of duty to the young men about him induced the author to deliver, and which Mr. Rennell heard only by accident, arose naturally out of those studies.

It was at the desire of the Lord Chancellor Brougham that the author wrote the essay on "Animal Mechanics;" and it was probably from a belief that the author felt the importance of the subjects touched upon in that essay, that his lordship was led to do him the further honour of asking him to join with him in illustrating the "Natural Theology" of Dr. Paley.

That request was especially important, as showing that the conclusions to which the author had arrived, were not the peculiar or accidental suggestions of professional feeling, nor of solitary study, which is so apt to lead to enthusiasm; but that the powerful and masculine mind of Lord Brougham was directed to the same objects: that he, who in early life was distinguished for his successful

* An office in the University of Cambridge.

prosecution of science, and who has never forgotten her interests amidst the most arduous and active duties of his high station, encouraged and partook of these sentiments.

Thus, from at first maintaining that design and benevolence were every where visible in the natural world, circumstances have gradually drawn the author to support these opinions more ostentatiously and elaborately than was his original wish.

The subject which he has to illustrate in this volume, belongs to no definite department; and is intermediate between those sciences which have been assigned to others. The conception which he has formed of its execution is, that setting out as from a single point, he should enlarge his survey, and show the extent of the circle, and the variety of subjects, upon which it bears; thence deducing the conclusion, that as there is a relation of one part to the whole, there must be a system, and universal design.

The author cannot conceal from himself the disadvantages to which he is exposed in coming before the public, not only with a work in some measure extra-professional, but with associates distinguished by classical elegance of style, as well as by science. He must entreat the reader to remember that he was, early and long, devoted to the study

of anatomy ; and with a feeling (right or wrong) that it surpassed all others in interest and usefulness. This made him negligent of acquirements which would have better fitted him for the honourable association in which he has been placed: and no one can feel more deeply that the suggestions which occur in the intervals of an active professional life, must always be unfavorably contrasted with what comes of the learned leisure of a College.

The author has to acknowledge his obligations to His Grace the Archbishop of Canterbury, the Bishop of London, and the late President of the Royal Society, for having assigned to him a task of so much interest. When he undertook it, he thought only of the pleasure of pursuing these investigations, and perhaps too little of what the public were entitled to expect from an Essay composed in circumstances so peculiar, and forming a part in this "great argument."

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THE HAND,

ITS MECHANISM AND VITAL ENDOWMENTS,

AS EVINCING DESIGN.

CHAPTER I.

If we select any object from the whole extent of animated nature, and contemplate it fully and in all its bearings, we shall certainly come to this conclusion: that there is design in the mechanical construction, benevolence in the endowments of the living properties, and that good on the whole is the result. We shall perceive that the sensibilities of the body have a relation to the qualities of things external, and that delicacy of texture is, therefore, a necessary part of its constitution. Wonderful, and exquisitely constructed, as the mechanical appliances are for the protection of this delicate structure, they are altogether insufficient; and a protection of a very different kind, which shall animate the body to the utmost

exertion, is requisite for safety. Pain, whilst it is a necessary contrast to its opposite pleasure, is the great safeguard of the frame. Finally, as to man, we shall be led to infer that the pains and pleasures of mere bodily sense (with yet more benevolent intention) carry him onward, through the developement and improvement of the mind, to higher aspirations.

To comprehend the perfection of the structure even of any single organ of an animal body, we must take it comparatively, that we may see how the same system is adapted to an infinite variety of conditions. This carries us necessarily into a new science, no less than that which regards the changes in the Earth's surface. And although in this comparison we shall find that there have been stupendous revolutions indicative of power, it is in contemplating the adaptation of new forms of living and organized matter to these successive changes in the surface of the earth, that we shall have the best proofs of the continuance of that Power which first created.

Such is the course of reasoning which I propose to follow in giving an account of the hand and arm; contrasting them, in the first place, with the corresponding parts of living creatures through all the divisions of the chain of vertebrated animals; and then taking the hand, not merely as combining the perfections of me-

chanical structure, but as possessing the property of touch, by which it ministers to and improves every other sense, and constitutes the organ in the body the most remarkable, for its correspondence with man's capacities.

Some may conceive that as I have for my title the Human Hand, and the relation of the solid structures of the animal frame, it will lead me to consider the body as a machine only. I neither see the necessity for this, nor do I acknowledge the danger of considering it in that light. I embark fearlessly in the investigation, convinced that, yielding to the current of thought, and giving the fullest scope to enquiry, there can be no hidden danger if the mind be free from vicious bias. I cannot see how scepticism should arise out of the contemplation of the structure and mechanism of the animal body.

Let us for a moment think what is the natural result of examining the human body as a piece of machinery, and see whether it makes the creation of man more or less important in relation to the whole scheme of nature.

Suppose there is placed before us a machine for raising great weights, be it the simplest of all, the wheel and axle. We are given to understand that this piece of mechanism has the property of multiplying the power of the hand. But a youth of subtile mind may say, I do not believe it possible so to multiply the power

of the hand; and if the mechanician be a philosopher, he will rather applaud the spirit of doubt. If he condescend to explain, he will say, that the piles driven into the ground, or the screws uniting the machinery to the beams, are the fixed points which resist in the working of the machine; that their resistance is a necessary condition, since it is thrown, together with the power of the hand, on the weight to be raised; and he will add that the multiplication of wheels does not alter the principle of action, which every one may see in the simple lever, to result from the resistance of the fulcrum or point, on which it rests.

Now grant that man's body is a machine, where are the points of resistance? are they not in the ground we stand upon? This leads us to enquire by what property we stand. Is it not by the weight of the body, or, in other words, by the attraction of the earth? The terms attraction, or gravitation lead at once to the philosophy of the question. We stand because the body has weight, and a resistance in proportion to the matter of the animal frame and the magnitude of the globe itself. We need not stop at present to observe the adjustment of the strength of the frame, the solidity of the bones, the elasticity of the joints, and the power of the muscles, to the weight of the whole. Our atten-

tion is directed to the relations which the frame has to the earth we are placed upon.

Some Philosophers, who have considered the matter curiously, have said, that if man were translated bodily to another planet, and that planet were smaller than the earth, he would be too light, and he would walk like one wading in deep water: on the contrary, if the planet were larger, the attraction of his body would make him feel as if his limbs were loaded with lead; nay, the attraction might be so great as to destroy the fabric of the body, crushing bones and all.*

However idle these fancies may be, there is no doubt that the animal frame is formed with a due relation to the earth we inhabit, and that the parts of the animal body, and we may say the strength of the materials, have as certainly a correspondence with the weight, as the wheels and levers of a machine, or the scaffolding which sustains them, have relation to the force and velocity of the machinery, or the load that they are employed to raise.

The mechanism and organization of animals have been often brought forward for a different purpose from that for which I use them. We find it said, that it is incomprehensible that an all

* The matter of Jupiter is as 330,600 to 1000 of our Earth. The diameter of Pallas is 80 miles; the Earth is 7,911 miles in diameter.

powerful Being should manifest his will in this manner; that mechanical contrivance implies difficulties overcome: and how strange it is, they add, that the perceptions of the mind, which might have been produced by some direct means, or have arisen spontaneously, should be received through an instrument so fine and complex as the eye;—and which requires the creation of the element of light, to enter the organ and to cause vision.

For my own part, I think it most natural to contemplate the subject quite differently. We perhaps presume too much when we say that light has been created for the purpose of vision. We are hardly entitled to pass over its properties as a chemical agent, its influence on the gases, and, in all probability, on the atmosphere, its importance to vegetation, to the formation of the aromatic and volatile principles and to fructification, its influence on the animal surface by invigorating the circulation, and imparting health. In relation to our present subject, it seems more rational to consider light second only to attraction in respect to its importance in nature, and as a link connecting systems of infinite remoteness.

To have a conception of this we must tutor our minds, and acquire some measure of the velocity of light, and of the space which it fills. It is not sufficient to say that it moves 200,000 miles in a second; for we can compre-

hend no such degree of velocity. If we are further informed that the earth is distant from the sun 95,000,000 of miles, and that light traverses the space in 8 minutes and 1-8th, it is but another way of affirming the inconceivable rapidity of its transmission. Astronomers, whose powers of mind afford us the very highest estimate of human faculties, whose accuracy of calculation is hourly visible, have affirmed that light emanates from celestial bodies at such vast distance that thousands of years shall elapse during its progress to our earth—yet that impelled by a force equal to its transmission through this space, it enters the eye, and strikes upon the delicate nerve with no other effect than to produce vision.*

Instead of supposing light created for the eye, and to give us the sense of vision, would it not be more conformable to a just manner of considering this subject, to dwell with admiration on the fact, that this small organ, the eye, should be formed with relation to a creation of such vast extent and grandeur:—and more especially, that the ideas arising in the mind through the influence of that matter and this organ, should be constituted a part of one vast whole!

By such considerations we are led to contem-

* The argument is not weakened on assuming the hypothesis, that light results from the movement of an elastic ether.

plate the human body in its different relations. The magnitude of the earth determines the strength of our bones, and the power of our muscles; so must the depth of the atmosphere determine the condition of our fluids, and the resistance of our blood vessels; the common act of breathing, the transpiration from the surfaces, must bear relation to the weight, moisture, and temperature of the medium which surrounds us. A moment's reflection on these facts proves that our body is formed with a just correspondence to all these external influences: and not the frame of the body only, but also the vital endowments and the properties of the organs of sense. It were a perverseness to say that the outward senses, the organization, and the vital properties, could arise from the influence of the surrounding elements, or out of matter spontaneously; they are created in accordance with the condition of the globe, and are systematic parts of a great whole.

These views lead to another consideration, that the complexity of our structure belongs to external nature, and not of necessity to the mind. Whilst man is an agent in a material world, and sensible to the influence of things external, complexity of structure is a necessary part of his constitution. But we do not perceive a relation between this complexity and the mind. From aught that we learn by this mode of study, the mind may be as distinct from the bodily organs

as the exterior influences are which give them exercise

Something, then, we observe to be common to our planet and to others, to our system and to other systems; matter, attraction, light; which nearly implies that the mechanical and chemical laws must be the same throughout. It is perhaps too much to affirm, with an anonymous author, that an inhabitant of our world would find himself at home in any other, that he would be like a traveller only, for a moment perplexed by diversity of climate and strangeness of manners, and confess, at last, that nature was every where and essentially the same. However this may be, all I contend for is the necessity of certain relations being established between the planet and the frames of all which inhabit it; between the great mass and the physical properties of every part; that in the mechanical construction of animals, as in their endowments of life, they are created in relation to the whole, planned together and fashioned by one Mind.

A comparison made between the system of an animal body, and the condition of the earth's surface, is highly illustrative of design in both. In the animal, we see matter withdrawn from the influences which arrange things that are dead and inorganic; but this matter, thus appropriated to the animal, and newly endowed through the influence of life, continues in possession of such

qualities of inanimate matter as are necessary to constitute the living being a part of the system—an inhabitant of the earth. To what then, does this argument lead? Is it not, that as the beautiful structure of the animal, and the perfection in the arrangement of its parts demonstrate design—so design extends to the condition of the earth also, and over both there is a ruling Intelligence?

Men who have studied deeply, and who have become authorities in natural science, acquire a happy spirit of contentment and true philosophy; of which we have examples in Grew,* in Ray, and in Linnæus. The last, resting from his great labours in universal nature, and struck with the perfection and order evinced in the whole, breaks out very naturally and eloquently in admiration of the just relation of all things, as proving them to be the work of one almighty Being. Then considering the great globe as a Museum,† furnished forth with the works of the Supreme Being, man, he adds, is placed in the midst of it, as alone capable of comprehending and valuing it. And if this be true, as certainly it is, what then becomes his duty?

* A naturalist, who wrote on the anatomy of Plants; also, "*Cosmologia sacra*, a Discourse on the Universe, as the creature and kingdom of God."

† These sentiments are best expressed in his Preface to the Catalogue of the Museum of Adolphus Frederick of Sweden.

Moralists and divines, with nature herself, testify that the purpose of so much beauty and perfection being made manifest to man, is that he may study and celebrate the works of God: and that if he fail in this, he will be wanting in those contemplations and exercises by which the mind is to be raised to the knowledge of God. Those who say that the Scriptures ought to be the sole guides, forget that these are addressed to intelligent beings; and what can be more fitting to bestow that intelligence and capacity which is to receive eternal truths, than the studies which the great naturalist is enforcing, when he says, "If we have no faith in the things which are seen, how should we believe those which are not seen? The brute creatures, although furnished with external senses, resemble those animals which, wandering in the woods, are fattened with acorns, but never look upwards to the tree which affords them food, much less have they an idea of the beneficent author of the tree and its fruit." By such reflections was Linnæus led to conclude, that "whoever shall regard with contempt the œconomy of the Creator here, is as truly impious as the man who takes no thought of the future."

The passiveness which is natural in infancy, and the want of reflection as to the sources of

enjoyment which is excusable in youth, become insensibility and ingratitude in riper years. In the early stages of life, before our minds have the full power of comprehension, the objects around us serve but to excite and exercise the outward senses. But in the maturity of reason, philosophy should present these things to us anew, with this difference, that the mind may contemplate them: that mind which is now strengthened by experience to comprehend them, and to entertain a grateful sense of them.

It is this sense of gratitude which distinguishes man. In brutes, the attachment to offspring for a limited period is as strong as in him, but it ceases with the necessity for it. In man, on the contrary, the affections continue, become the sources of all the endearing relations of life, and the very bonds by which society is connected.

If the child, upon the parent's knee, is unconsciously incurring a debt, and strong affections grow up so naturally that nothing is more universally condemned than filial ingratitude, we have but to change the object of affection, to find the natural source of religion itself. We must show that the care of the most tender parent is in nothing to be compared with those provisions for our enjoyment and safety, which it is not only beyond the ingenuity of man to

supply to himself, but which he can hardly comprehend, while he profits by them.

If man, of all living creatures, be alone capable of gratitude, and through this sense be capable also of religion, the transition is natural; since the gratitude due to parents is abundantly more owing to Him "who saw him in his blood, "and said, Live."

For the continuance of life, a thousand provisions are made. If the vital actions of a man's frame were directed by his will, they are necessarily so minute and complicated, that they would immediately fall into confusion. He cannot draw a breath, without the exercise of sensibilities as well ordered as those of the eye or ear. A tracery of nervous cords unites many organs in sympathy; and if any one filament of these were broken, pain and spasm and suffocation would ensue. The action of his heart, and the circulation of his blood, and all the vital functions are governed through means and by laws which are not dependant on his will; and to which the powers of his mind are altogether inadequate. For had they been under the influence of his will, a doubt, a moment's pause of irresolution, a forgetfulness of a single action at its appointed time, would have terminated his existence.

Now, when man sees that his vital operations

could not be directed by reason—that they are constant, and far too important to be exposed to all the changes incident to his mind, and that they are given up to the direction of other sources of motion than the will, he acquires a full sense of his dependance. If he be fretful and wayward, and subject to inordinate passion, we perceive the benevolent design in withdrawing the vital motions from the influence of such capricious sources of action, so that they may neither be disturbed like his moral actions, nor lost in a moment of despair.

Ray, in speaking of the first drawing of breath, delivers himself very naturally: "Here, "methinks, appears a necessity of bringing in "the agency of some superintendent intelligent "being, for what else should put the diaphragm "and the muscles serving respiration in motion "all of a sudden so soon as ever the fœtus is "brought forth? Why could they not have "rested as well as they did in the womb? What "aileth them that they must needs bestir them-"selves to get in air to maintain the creature's "life? Why could they not patiently suffer it "to die? You will say the spirits do at this "time flow to the organs of respiration, the "diaphragm, and other muscles which concur to "that action and move them. But what raises "the spirits which were quiescent, &c., I am "not subtile enough to discover."

We cannot call this agency a new intelligence different from the mind, because, independently of consciousness, we can hardly so define it. But a sensibility is bestowed, which being roused (and it is excited by the state of the circulation,) governs these muscles of respiration, and ministers to life and safety, independently of the will.

When man thus perceives, that in respect to all these vital operations he is more helpless than the infant, and that his boasted reason can neither give them order nor protection, is not his insensibility to the Giver of these secret endowments worse than ingratitude? In a rational creature, ignorance of his condition becomes a species of ingratitude; it dulls his sense of benefits, and hardens him into a temper of mind with which it is impossible to reason, and from which no improvement can be expected.

Debased in some measure by a habit of inattention, and lost to all sense of the benevolence of the Creator, he is roused to reflection only by overwhelming calamities, which appear to him magnified and disproportioned; and hence arises a conception of the Author of his being more in terror than in love.

There is inconsistency and something of the child's propensities still in mankind. A piece of mechanism, as a watch, a barometer, or a dial,

will fix attention—a man will make journeys to see an engine stamp a coin, or turn a block ; yet the organs through which he has a thousand sources of enjoyment, and which are in themselves the most exquisite in design, and the most curious both in contrivance and mechanism do not enter his thoughts ; and if he admire a living action, that admiration will probably be more excited by what is uncommon and monstrous, than by what is natural and perfectly adjusted to its office—by the elephant's trunk, than by the human hand. This does not arise from an unwillingness to contemplate the superiority or dignity of our own nature, nor from an incapacity of admiring the adaptation of parts. It is the effect of habit. The human hand is so beautifully formed, it has so fine a sensibility, that sensibility governs its motions so correctly, every effort of the will is answered so instantly, as if the hand itself were the seat of that will; its actions are so powerful, so free, and yet so delicate, as if it possessed a quality of instinct in itself, that there is no thought of its complexity as an instrument, or of the relations which make it subservient to the mind ; we use it as we draw our breath, unconsciously, and have lost all recollection of the feeble and ill-directed efforts of its first exercise, by which it has been perfected. Is it not the very perfection of the instrument which makes us insensible to its use ? A vulgar admiration is

excited by seeing the spider-monkey pick up a straw, or a piece of wood, with its tail; or the elephant searching the keeper's pocket with his trunk. Now, if we examined the peculiarity of the elephant's structure fully, that is to say, from its huge mass deduced the necessity for its form, and from the form the necessity for its trunk, it would lead us, through a train of very curious observations, to a more correct notion of that appendage, and therefore to a truer admiration of it; but I contrast this part with the human hand, merely to show how insensible we are to the perfections of our own frame, and to the advantages attained through such a form. We use the limbs without being conscious, or, at least, without any conception of the thousand parts which must conform to a single act. To excite attention, the motions of the human frame must either be performed in some mode that is strange and unexpected, such as will raise the wonder of the ignorant and vulgar; or we must rouse ourselves, by an effort of the cultivated mind, to observe things and actions of which the sense has been lost, as we have said, by long familiarity.

In the following pages, I shall treat the subject comparatively, and exhibit a view of the bones of the arm, descending from the human hand to the fin of the fish. I shall in the next place review the actions of the muscles of the

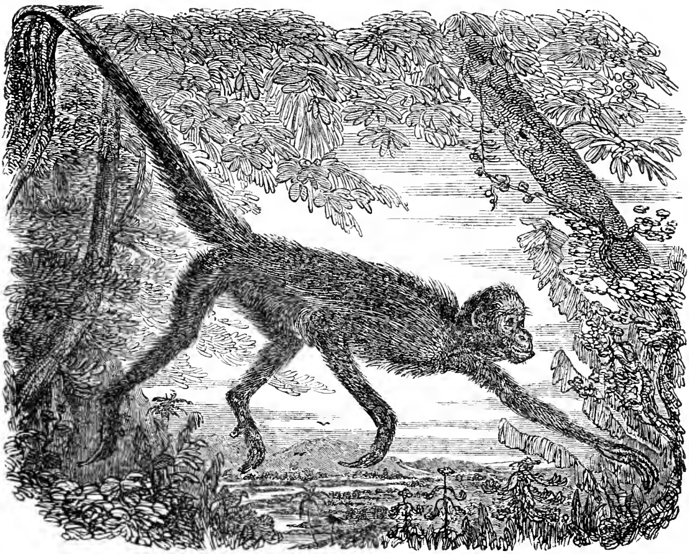
arm and hand. Then proceeding to the vital properties, I shall advance to the subject of sensibility, leading to that of touch; afterwards, I shall show the necessity of combining the muscular action with the exercise of the senses, and especially with that of touch, to constitute the hand, what it has been called, the geometrical sense. I shall describe the organ of touch, the cuticle and skin, and arrange the nerves of the hand according to their functions. I shall then enquire into the correspondence between the capacities or endowments of the mind, and the external organs, and more especially the properties of the hand; and conclude by showing that animals have been created with a reference to the globe they inhabit; that all their endowments and various organization bear a relation to their state of existence, and to the elements around them; that there is a plan universal, extending through all animated nature, and which has prevailed in the earliest condition of the world; and finally, that on the most minute or the most comprehensive study of those subjects we every where behold prospective design.

CHAPTER II.

We ought to define the hand as belonging exclusively to man—corresponding in its sensibility and motion with the endowments of his mind, and especially with that ingenuity which, through means of it, converts the being, who is the weakest in natural defence, to be the ruler over animate and inanimate nature.

If we describe the hand, including the arm, as an extremity which has the thumb and fingers opposed to each other, so as to form an instrument of prehension, we embrace in the definition the extremities of the quadrumana or monkeys. Now, as these animals possess four such hands, it implies that we include the posterior as well as the anterior extremities. But the anterior extremity of the monkey is as much a foot as the posterior extremity is a hand; both are cal-

culated for their mode of progression, climbing, and leaping from the branches of trees, just as



the tail in some species is converted to the same purpose, and is as useful an instrument of suspension as any of the four extremities.*

The armed extremities of a variety of animals give them great advantages. But if man pos-

* This is a sketch of the Coaita, or Spider Monkey, so called from the extraordinary length of its extremities, and from its motions. The tail answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging by the foot, sometimes by the fore extremity, but oftener and with a greater reach by the tail. The prehensile part of the tail is covered only with skin, forming an organ of touch as discriminating as the proper extremities. The Caraya, or

sessed similar provisions, he would forfeit his sovereignty over all. As Galen, long since, observed, "did man possess the natural armour of the brutes, he would no longer work as an artificer, nor protect himself with a breast-plate, nor fashion a sword or spear, nor invent a bridle to mount the horse and hunt the lion. Neither could he follow the arts of peace, construct the pipe and lyre, erect houses, place altars, inscribe laws, and through letters and the ingenuity of the hand hold communion with the wisdom of antiquity, at one time to converse with Plato, at another with Aristotle, or Hippocrates."

But the hand is not a distinct instrument; nor is it properly a superadded part. The whole frame must conform to the hand, and act with reference to it. Our purpose will not be answered by examining it alone; we must extend our views to all those parts of the body which are in strict connexion with the hand. For example, the bones from the shoulder to the finger ends, have a relation established amongst them which

Black howling monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so struck with the property of the tail of the Ateles, as to compare it with the proboscis of the elephant. They have assured us that they fish with it.

The most interesting use of the tail is seen in the Opossum. The young of that animal mount upon her back, and entwine their tails around their mother's tail, by which they sit secure, while she escapes from her enemies.

makes it essential to examine the whole extremity. And in order fully to comprehend the fine arrangement of the parts necessary to the motions of the fingers, we must compare the structure of the human body with that of other animals.

Were we to limit our enquiry to the bones of the arm and hand in man, no doubt we should soon discover their provisions for easy, varied, and powerful action; and conclude that nothing could be more perfectly suited to their purposes. But we must extend our views to comprehend a great deal more,—a greater design.

By a skeleton, is understood the system of bones, placed internally, which gives firmness and the characteristic form to the animal, and receives the action of the exterior muscles. This system belongs, however, only to one part of the animal kingdom; that higher division,—the animalia vertebrata,* which includes the chain of beings, from man to fishes.

The most essential function to life is respiration; and the mode in which this is performed, that is to say, the manner in which the decarbonization of the blood is effected through its exposure to the atmosphere, produces a remarkable change in the whole frame-work of the animal

* See the Classification at the end of the volume,—also the first of the Additional Illustrations.

body. As man, the mammalia, birds, reptiles, and fishes have much of the mechanism of respiration in common, so there is a resemblance through them all, in the texture of the bones, in the action of the muscles, and in the arrangement of the nerves. They all possess the vertebral column or spine; and the existence of this column not only implies an internal skeleton, but that particular frame-work of ribs, which is suited to move the lungs in breathing. But the ribs do not move of themselves, they must have appropriate muscles. These muscles must have their appropriate nerves: and for supplying these nerves there must be a spinal marrow. The spinal canal formed within the vertebral column is as necessary to the spinal marrow as the skull is to the brain. So that we come round to understand the necessity of a vertebra to the formation of the spinal marrow; and the reader may comprehend how much enters into the conception of the anatomist or naturalist, when the term is used, a vertebrated animal,* viz:—an internal skeleton, a particular arrangement of respiratory organs, and a conformity in the nervous system.

It is to this superior division of vertebrated

* *Vertebra* is the name given to the individual bones of the spine, or back-bone. See the explanation of Vertebral Animals, in the Classification at the end of the volume.

animals that I shall limit myself, in making a review of the bones of the upper extremity.

In commencing this subject, if I were to indulge in the admiration naturally arising out of it, and point to the strength and the freedom of motion, in the upper extremity, at the ball and socket joint of the shoulder,—the firmness of the articulation of the elbow, and yet how admirably it is suited to the co-operation of the hands, the latitude of motion in the wrist joint, combined with strength, and the fineness of the motion of the hand itself, divided among the joints of twenty-nine bones, some might object, with a show of reason, and say—The bones and the forms of the joints which you are admiring, are so far from being peculiarly suited to the hand of man, that they may be found in any other vertebrated animal. But this would not abate our admiration; it would only induce us to take a more comprehensive view of nature; and remind us that our error consisted in looking at a part only, instead of embracing the whole system; where by slight changes and gradations in the forms, hardly perceptible, the same bones are adjusted to every condition of animal existence.

Nothing can be more correctly adapted and appropriate for their object, than the bones through which the motions of the upper extremity are produced; we enjoy the power of bending and

coiling the arm, with the most extensive and free motion—and of reaching the fingers to every part: yet these bones, so truly admirable in man, we recognise in the fin of the whale, in the paddle of the turtle, and in the wing of the bird. We see the same bones, perfectly suited to their purpose, in the paw of the lion or the bear, and equally fitted for motion in the hoof of the horse, or in the foot of the camel, or adjusted for climbing or digging in the long clawed feet of the sloth or bear.

It is obvious, then, that we should be occupied with too limited a view of our subject, were we to consider the human hand in any other light than as presenting the most perfect combination of parts: as exhibiting the bones and muscles which in different animals are suited to particular purposes, so combined in the hand as to perform actions the most minute and complicated, consistently with powerful exertion.

The wonder still is, that whether we examine this system in man, or in any of the inferior species of animals, nothing can be more curiously adjusted or appropriated; and we should be inclined to say, whatever instance occupied our thoughts for the time, that to this particular object the system had been framed.

The view which the subject opens, is unbounded. The curious synthesis by which we ascertain the nature, condition, and habits of

an extinct animal, from the examination of its fossil remains, is grounded on a knowledge of the system of which we are speaking; and to make the proper use of this department we must understand what a fossil bone is.

A bone consists of many parts; but for our present purpose it is only necessary to observe that the hard substance, which we familiarly recognise as bone, is formed of an earthy material, the phosphate of lime, every where penetrated by membranes and vessels as delicate as those which belong to any other part of the body. Fossil bones are those which are found imbedded in the earth, and may be in different conditions. They either retain their natural structure, or may have become petrified; that is to say, the animal matter may have been decomposed and dissipated, with the phosphoric acid of the phosphate of lime; and then, silicious earth, or lime in composition with iron, or iron pyrites, may by solution and infiltration fill the interstices of the original earthy matter of the bone. Thus it will be converted into stone, and be as permanent as the rock which contains it: and it will retain the form though not the internal structure of bone. Now that form, in consequence of the perfect system which we have hinted at, becomes a proof of revolutions in the globe the most extraordinary. By reasoning on such fossil bones, the mind of

the enquirer is carried back, not merely to the contemplation of the structure of the animal of which they are the remains, but by inference, from the animal organization to the changes in the globe itself.

The remains of marine animals are found in the highest mountains of the old and new world, and on turning up the surface of our fields, or in the beds of rivers, huge bones are discovered; and not in the loose soil only, but under the solid limestone rock. The bones thus exposed become naturally a subject of intense interest, and are unexpectedly connected with the enquiry in which we are engaged. Among other important conclusions they lead to this—that there is not only a scheme or system of animal structure pervading all the classes of animals which now inhabit the earth, but that the principle of this great plan of creation was in operation, and governed the formation of those animals which existed previous to the revolutions that the earth has undergone: that the excellence of form now seen in the skeleton of man, was in the scheme of animal existence long previous to the formation of man, and before the surface of the earth was prepared for him or suited to his constitution, structure, or capacities.

A skeleton is dug up which has lain under many fathoms of rock, being the bones of an animal that lived antecedent to that formation

of rock, and at a time when the earth's surface must have been in a condition very different from what it is now. These remains prove that this animal must have been formed of the same elements constituent as those of the present day, that it had analogous organs — received new matter by digestion, and was nourished by means of a circulating fluid—possessed feeling through a nervous system, and was moved by the action of muscles: and with regard to the animals that lived at the same period, we may infer that their organs of digestion, circulation, and respiration were modified by circumstances, and in accordance with their habits and modes of living, as in the animals now alive. Such changes in the organs are but variations in the system by which new matter is assimilated to the animal body,—and however remarkable they may be, they always bear a certain relation to the original type, as parts of the same great design.

In examining these bones of the ancient world, so regularly are they formed on the same principle which is evident in the animals now inhabiting the earth, that by observing their shape, and the processes* by which their muscles were attached, we can reduce the animals to

* Processes are the projecting parts of bone by which the tendons of the muscles are attached. The processes, therefore, to the anatomist are indications of the conditions of the muscles.

which they belonged, to their orders, genera, and species, with as much precision as if the recent bodies had been submitted to the eye of the anatomist. Not only can we demonstrate that their feet were adapted to the solid ground, or to the oozy bed of rivers,—for speed, or for grasping and tearing; but judging, by these indications, of the habits of the animals, we acquire a knowledge of the condition of the earth during their period of existence: that it was suited at one time to the scaly tribe of the lacertæ, with languid motion; at another, to animals of higher organization, with more varied and lively habits; and finally we learn, that at any period previous to man's creation, the surface of the earth would have been unsuitable to him.

We ought not to touch on this subject without one observation more. When the peasant suspends his work on turning up the great bones of some unknown animal, and thinks that he has discovered the limbs of a giant, he is more excusable than the learned and ingenious, who seek to illustrate the Scriptures by these natural appearances. True religion is adapted to the sound capacities of every man—to that condition of mind which the individual experience of the good and evil of the world, sooner or later, brings with it. It is suited to man in every stage of the progress of society—to his weakness and to his

strength; by which it is the real dispenser of equal rights. Our religion could not have been adapted to every man had it been framed with a relation to science; and least of all with a relation to that branch of natural knowledge which is called geology—a science so obviously in its infancy, that but for the alliance with anatomy, it would have continued to present a scene only of confusion for ignorant wonderment.

It may then be asked why we cultivate those scientific views to which we apply the term natural religion? Because they agreeably enlarge our comprehension, and exalt the imagination, while they repress a too selfish enthusiasm. We all have proceeded a certain length in the examination of natural phenomena; and the convictions arising from the survey are wrought into the opinions of every one. Yet we experience a fresh and cheerful influence when benevolent design is disclosed by new facts, or by things that are familiar being presented in a new light. We are sensible of a renewed impulse; a gratification which interferes with no duty.

We may take this opportunity of correcting a notion which we have seen expressed, of certain imperfections being discoverable in the structure of some animals: an idea which has sprung from comparing these animals with ourselves,

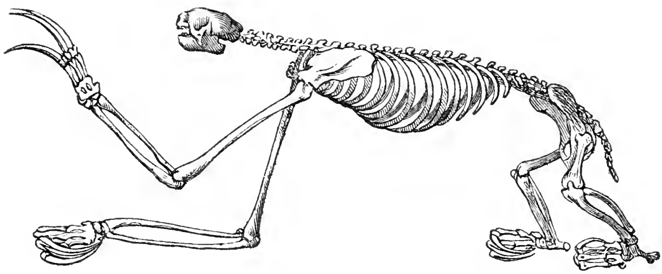
our structure, and sensibilities, instead of looking on them with reference to their peculiar conditions.

For example, the eloquent Buffon, when comparing the present races of animals with the fossil remains of individuals of the same family, which are extinct, expresses some singular opinions; which, with some reserve, have been adopted even by Cuvier. Buffon speaks confidently of the unsuitableness of the organs of animals, and the derangement of their instincts. But in this he compares their mode of life with the state of human society, where individuals are subject to misery and want. He surely sympathizes too closely with the bird of prey, when he characterises its watchfulness as a lively picture of wretchedness, anxiety, and indigence. If a bird refuse to be domesticated and crammed with meat, it is hardly fair to accuse it of gloom and apathy, when the simple fact is that it is treated contrary to its natural habits and instincts. The animals which he principally commiserates, are of the tardigrade family. In the Ai,* for example, the defect of organization he supposes to be the greatest; and the Unau,† he considers only a little less miserably provided for existence.

* Bradypus Tridactylus :—bradypus *(slow footed)*, tridactylus *(three toed)*, of the order EDENTATA *(wanting incisor teeth)*.

† Bradypus didactylus.

In the same manner, modern travellers express pity for these animals. Whilst other quadrupeds, they say, range in boundless wilds, the



sloth hangs suspended by his strong arms,—a poor ill-formed creature, deficient as well as deformed, his hind legs too short, and his hair like withered grass; his looks, motions, and cries conspire to excite pity; and, as if this were not enough, they say that his moaning makes the tiger relent and turn away. This is not a true picture: the sloth cannot walk, like many other quadrupeds, but he stretches out his arms,—and if he can hook on his claws to the inequalities of the ground, he drags himself along. This is the condition which gives occasion to such an expression as "the bungled and faulty composition of the sloth." But if he can reach the branch or the rough bark of a tree, then will his progress be rapid; he will climb hand over head along the branches till they touch, and thus get

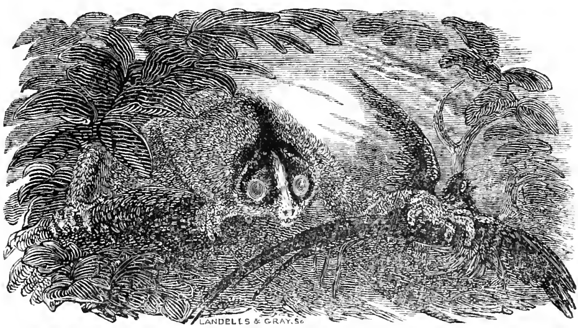
from bough to bough, and from tree to tree; he is most alive in the storm; it is when the wind blows, and the trees stoop, and the branches wave and meet, that he is upon the march.

Accordingly, the compassion expressed by these philosophers for the animals which they consider imperfectly organized, is uncalled for.* As well might they pity the larva of the summer fly, which creeps at the bottom of a pool, because it cannot yet rise upon the wing. As the insect has no impulse to fly, until its metamorphosis is perfect and its wings developed, so there is no reason to suppose that a disposition or instinct is given to animals without a corresponding provision for motion. On the ground, the sloth may move tardily; his long arms and preposterous claws may then be an incumbrance; but they are of advantage in his natural place, among the branches of trees, in obtaining his food, and in giving him shelter and safety from his enemies.

It is not by our own sensations, that we must estimate the motions of animals. The motion of the bill of the swallow, or of the fly-catcher, in catching a fly, is so rapid that we do not see it, but only hear the snap. On the contrary, how very different are the means employed by the chamelion for obtaining his food; he lies more

* The subject is pursued at the end of the following chapter.

still than the dead leaf, his skin like the bark of the tree, and taking the hue of the surrounding objects: whilst other animals have excitement conforming to their rapid motions, his shrivelled face hardly indicates life; his eyelids are scarcely parted; he protrudes his tongue towards the insect, with a motion so imperceptible, that it is touched and caught more certainly than by the most lively action. Thus, various creatures, living upon insects, reach their prey by different means and instincts; some have rapidity of motion, which gives no time for escape, while others have a languid and slow movement that excites no alarm.



The loris, a tardigrade animal, might be pitied too for the slowness of its motions, if these were not necessary to its very existence. It steals on its prey by night, and extends its arm towards the bird on the branch, or the great moth, with a motion so imperceptibly slow, as to make sure

of its object.* Just so the Indian, perfectly naked, his hair cut short, and his skin oiled, creeps under the canvass of the tent, and moving like a ghost, stretches out his hand with a motion so gentle as to displace nothing, and not even to disturb those who are awake and watching. Against such thieves, we are told, it is hardly possible to guard. And thus, the necessities or vicious desires of man subjugate him, and make him acquire by practice the wiliness implanted in brutes as instinct. Or we may say that endowed with reason, man is brought to imitate the irrational creatures, and so to vindicate the necessity for their particular instincts; of which every class affords examples. The illustrations of such actions are as striking, in insects, as in the loris, or the chamelion. Evelyn describes the spider *(aranea scenica)* as exhibiting remarkable cunning in catching a fly. "Did the fly, (he says,) happen not to be within a leap, the spider

* It may be well to notice some other characters that belong to animals which prowl by night, and are inhabitants of the tropical regions. The various creatures that enliven the woods in the day-time, in these warm climates, have fine skins, and smooth hair; but those that seek their prey at night have a thick coat like animals of the arctic regions. What is this but to be clothed as the sentinel whose watch is in the night? They have eyes, too, which from their peculiar structure, are called nocturnal, being formed to admit a large pencil of rays of light, and having the globe full and prominent, and the iris contractile, to open the pupil to the greatest extent. We have seen how their motions and instincts correspond with their nocturnal habits.

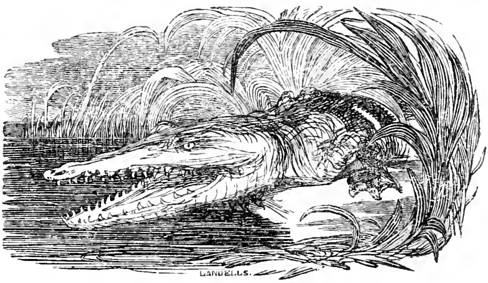
would move towards it, so softly, that its motion seemed not more perceptible than that of the shadow of the gnomon of a dial," * and then it would suddenly pounce upon its prey.

I would only remark further, that we are not to account this slowness a defect, but rather an appropriation of muscular power: since in some animals, the same muscles which at one time, produce a motion so slow as to be hardly perceptible, can at another act with the velocity of a spring.

Now Buffon, speaking of the extinct species of the tardigrade family, has represented them as monsters, by defect of organization: as attempts of nature, wherein she has failed to perfect her plan: inferring that she has produced animals which must have lived miserably, and which she has effaced as failures from the list of living beings. The Baron Cuvier does not express himself more favourably, when he says of the existing species, that they present so little resemblance to the organization of animals gene-

* The passage continues—" if the intended prey moved, the spider would keep pace with it exactly as if they were actuated by one spirit, moving backwards, forwards, or on each side without turning. When the fly took wing, and pitched itself behind the huntress, she turned round with the swiftness of thought, and always kept her head towards it, though to all appearance as immoveable as one of the nails driven into the wood on which was her station; till at last, being arrived within due distance, swift as lightning she made the fatal leap, and secured her prey."—Evelyn, as quoted by Kirby and Spence.

rally, and their structure is so much in contrast with other creatures, that he could believe they were the remnants of an order unsuited to the present system of nature; and we must seek for their congeners in the interior of the earth, in the ruins of the ancient world.



But the animals of the Antediluvian world were not monsters; there was no lusus or extravagance. Hideous as they appear, and like the phantoms of a dream, they were adapted to the condition of the earth when they existed. I could have wished that our naturalists had applied to the inhabitants of that early condition of the globe, names less scholastic. We have the plesiosaurus, and plesiosaurus dolichodeiros, the ichthyosaurus, megalosaurus, and hylœosaurus, and igùanodon, pterodactyles, with long and short beaks, tortoises, and crocodiles; these are found among reeds and grasses of gigantic proportions, algæ and fuci; and a great variety of mollusca, of inordinate bulk compared with those of the present day, as ammonites and

nautili are discovered in the same spots. Every thing declares that these animals inhabited shallow seas, and estuaries, or great inland lakes: that the surface of the earth, at these parts, did not rise up in peaks and mountains, or perpendicular rocks bound in the seas; but that it was flat, slimy, and covered with a loaded and foggy atmosphere. Looking to the class of animals, as we have enumerated them, such a condition of the earth would correspond with them: they were scaly; they swam in water, or crept upon the margins; they were not exposed to animals possessing greater rapidity of motion, nor were there birds of prey to stoop upon them; there was, in short, a balance of the power of destruction and of self-preservation, the same as we see now to obtain in higher animals since created, with infinitely varied instincts and means for defence or attack. There is, indeed, every reason to believe that at that period, the classes mammalia and birds were not created. And it seems obvious if man had been placed upon the earth, when it was in this condition, he must have had around him a state of things neither suited to his constitution, nor calculated to call forth his capacities.

It is hardly possible to watch the night and view the break of day in a fine country, without being sensible that our pleasantest perceptions refer to the scenery of nature; and that we have feelings in sympathy with every successive

change, from the first streak of light until the whole landscape is displayed in valleys, woods, and sparkling waters. The changes on the scene are not more rapid than the transitions of the feelings which attend them. Now, all these sources of enjoyment, the clear atmosphere and the refreshing breezes, are as certainly the result of the several changes which the Earth's surface has undergone, as the displaced strata within its crust are demonstrative of these changes. We have every reason to conclude that these revolutions, whether they have been slowly accomplished and progressively, or by sudden, vast and successive convulsions, were necessary to prepare the earth for that condition which should correspond with the faculties to be given to man, and be suited to the full exercise of his reason, as well as to his enjoyment.

If a man contemplate the common objects around him—if he observe the connection between the qualities of things external and the exercise of his senses, between the senses so excited, and the condition of his mind, he will perceive that he is in the centre of a magnificent system, which has been prepared for his reception by a succession of revolutions affecting the whole globe, and that the strictest relation is established between the intellectual capacities and the material world.

In the succeeding chapter we shall take a

comparative view of the anatomy of the arm; and as we trace the same parts through different genera and species of animals, some extraordinary changes in their forms will be presented. But before proceeding to make this survey, we are naturally called upon to notice certain opinions which prevail on the subject.

However interesting the recent enquiries of geologists may be, they encourage a certain licence of fancy. During the remote periods, dark in every sense, when mounds of stratified rock were forming under interminable seas, what were the animated beings suited to live in the then condition of the elements, must be matter of conjecture. Materialists have long entertained the question, did the first egg proceed from a bird, or the bird from the egg?—But the hundred and ninety-nine theories on the sources of life and organization and the origin of animals, whether by ancient or modern philosophers, are all fanciful, wild, and unphilosophical, having no ground to rest upon!—Nothing is satisfactory until it is declared and believed that it has been the will of an Omnipotent Being to create—to form the earth and to give life—and that it was HE who appointed the changes to be wrought on the material, and gave the animating principle to produce organization in correspondence with these changes.

We have already hinted, that geologists have

discovered, in the stratified rocks composing the crust of the earth, proofs of a regular succession of formations; and that animals of very different structure have been imbedded, and are preserved in these successive layers. In the earlier formed strata animals are found which are low, as we choose to express it, in the chain of existence; in higher strata, oviparous reptiles of great bulk, and more complex structure, are discovered; above the strata containing these oviparous reptiles, there are found mammalia; and in the looser and more superficial strata are the bones of the mastodon, megatherium, rhinoceros, and elephant, &c. We must add that geologists agree that man has been created last of all.

Upon these facts, a theory is raised, that there has been a succession of animals gradually increasing in the perfection of their structure; that the first impulse of nature was not sufficient to the production of the highest and most perfect, and that it was only in her mature efforts that mammalia were produced.

But we are led to this reflection: that the very formation of a living animal, the bestowing life on a corporeal frame, however simple the structure, is of itself an act of creative power so inconceivably great, that we cannot regard any change in the organization, such as providing bones and muscles, or producing new organs of sense, as evincing a higher effort of that

power. In exploring therefore the varieties of animated nature, at these distinct epochs, we have a better guide, when we acknowledge the manifest design with which all has been accomplished; and the adaptation of the animals, their size, their economy, their organs, and instruments, to their condition.

Whether we make the most superficial or most profound examination of animals in their natural state, we shall find that the varieties are so balanced as to ensure the existence of all. This, we think, goes far to explain why the remains of certain animals are found in strata which indicate a peculiar condition of the earth's surface; and why only particular animals are found grouped together. For, as we may express it, if there had been an error in the grouping, there must have been a destruction of the whole; because the balance necessary to their existence must have been destroyed.

We know very well that so minute a thing as a fly will produce millions of the same kind, which, if not checked, will ere long darken the air and render whole regions desolate: so that if the breeze does not carry them in due time into the desert or into the ocean, the ravages committed by them will be most fearful. As in the present day every creature has its natural enemy, or is checked in production, sometimes by a limited supply of food, some-

times by disease, or by the influence of seasons; and as in the whole a balance is preserved, we may reasonably apply the same principle to explain the condition of things existing in the earlier stages of the world's progress. Certainly, by what we have as yet discovered in the grouping of animals, in the different stratifications or deposits of the earth, this view is borne out.

If the Naturalist or Geologist, exploring the rocks of secondary formation, should find animals of the class Mollusca inclosed within them, it agrees with his preconceived notions, that animals of their simple structure alone existed during the subsidence of the material of which the rock consists. But if the spine of a fish, or a jawbone, or a tooth, be discovered, he is much disturbed; because here is the indication of an animal having been at that time formed on a different type,—on that plan which belongs to animals of a superior class. Had he, on the contrary, supposed that animals were created with a relation to those circumstances, to which we have just alluded, the discovery of these remains would only imply that certain animals, which had hitherto increased undisturbed, had arrived at a period when their numbers were to be limited; or that the condition of the elements, and the abundance of food were now suited to the existence of a species of the vertebrata.

The principle, then, in the application of

which we shall be borne out, is, that there is an adaptation, an established and universal relation between the instincts, organization, and instruments of animals, on the one hand, and the elements in which they are to live, the position which they are to hold, and their means of obtaining food, on the other ;—and this holds good with respect to the animals which have existed, as well as those which now exist.

In discussing the subject of the progressive improvement of organized beings, it is affirmed that man, the last created of all, is not superior in organization to the others ; and that if deprived of intellectual power, he is inferior to the brutes. I am not arguing to support the theory of the gradual developement and improvement of animals ; but, however indifferent to the tendency of the argument, I must not admit the statement. Man is superior in organization to the brutes,—superior in strength—in that constitutional property which enables him to fulfil his destinies by extending his race in every climate, and living on every variety of nutriment. On the other hand, gather together the most powerful brutes, from the arctic circle or torrid zone, to some central point—so ill suited is their constitution to the change, that diseases will be generated, and they will be destroyed. With respect to the superiority of man being in his mind, and not merely in the provisions of his

body, it is no doubt true ;—but as we proceed, we shall find how the Hand supplies all instruments, and by its correspondence with the intellect, gives him universal dominion. It presents the last and best proof in the order of creation, of that principle of adaptation which evinces design.

Another opinion requires to be noticed. It is alleged that the variety of animals existing in the world is not a proof of design, or of there being a relation between the formation of their organs and the necessity for their exercise ; but it is supposed that the circumstances in which the animals have been placed are the cause of the variety. It is pretended, that, in the long progress of time, the influence of these circumstances has been such as to produce a complication of structure out of an animal which was at first simple. We shall reserve the discussion of this theory until we have the data before us ; which alone, without much argument, will suffice, we think, to overthrow it.

I may notice shortly another idea entertained by some naturalists, who are pleased to reduce these differences in the structure of animals into general laws. It is affirmed that in the centre of the animal body, no disposition to change is manifested ; whilst in the extremities on the contrary, surprising variations of form are exhibited. If this be a law, there is no more to be said about it ; the enquiry is terminated. But I con-

tend that the term is quite inapplicable, and worse than useless, as tending to check enquiry. What is the meaning of the variation in the form being most common in the extremities, whilst towards the centre of the skeleton there is comparative permanence? I conceive the rationale to be this; that the central parts, by which in fact we mean the skull, spine, and ribs, are permanent in their offices; whilst the extremities vary and are adapted to every exterior circumstance. The office of the back part of the skull is to protect the brain, that of the spine to contain the spinal marrow, and that of the ribs to perform respiration. Why should we expect these parts to vary in shape while their office remains the same? But the shoulder on the contrary must vary in form, as it does in motion, in different animals. The shape of the bones and of the joints in all the parts of the extremities must be adapted to their various actions; and the carpus, or the tarsus, and phalanges * must change more than all the rest, to accommodate the extremity to its different offices. Is it not more pleasing to see the reason of this most surprising adjustment, than merely to say it is a law? †

There is yet another opinion, which after perusing the following chapter, will suggest itself to

* Carpus, the wrist; tarsus, the ankle or instep; phalanges, the rows of bones forming the fingers or toes.

† See the additional illustrations.

those who have read the more modern works on Natural History. It is supposed that the same elementary parts belong to all animals; and that the varieties in their structure are attributable to the transposition of these elementary parts. I find it utterly impossible to follow up this system to the extent which its abettors would persuade us to be practicable. I object to it as a means of engaging us in very trifling pursuits—and of diverting the mind from the truth; from that conclusion, indeed, to which I may avow it to be my intention to carry the reader. But this discussion also must follow the examples; and we shall resume it in a latter part of the volume.

CHAPTER III.

The Comparative Anatomy of the Hand.

In this enquiry, we have placed before us what in the strictest sense of the word is a system. All the individuals of the extensive division of the animal kingdom which we are about to review, viz. the vertebrated animals, possess a cranium for the protection of the brain,—a heart, implying a peculiar circulation,—and five distinguishable organs of sense. But the grand peculiarity, whence the term vertebrated is derived, is to be found in the spine; that chain of bones which connects the head and body, and, like a keel, serves as the foundation of the ribs, or as the basis of the fabric through which respiration is performed.

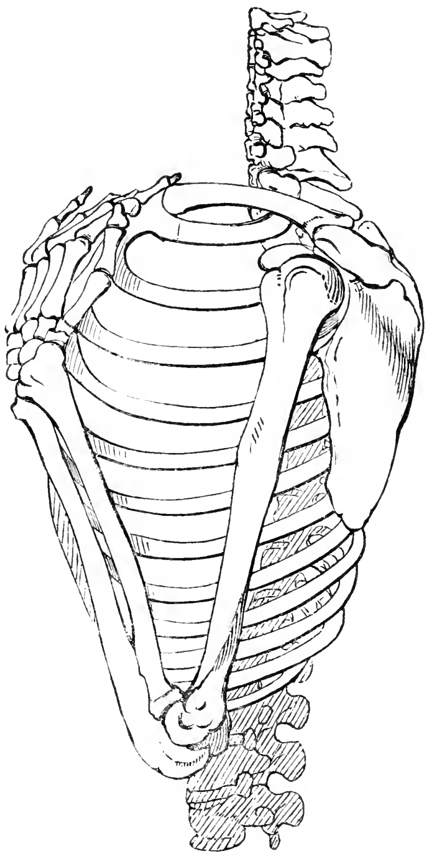
We are to confine ourselves, as we have said, to a portion only of this combined structure; to examine separately the anterior extremity, and

to observe the adaptation of its parts, through the whole range of these animals. We shall view it as it exists in man, and in the higher division of animals which give suck, the mammalia—and in those which propagate by eggs, the oviparous animals, birds, reptiles, amphibia, and fishes. In so doing, we shall find the bones composing it identified by certain common features, and yet adjusted to various purposes, in all the series from the arm to the fin. We shall recognise the same bones formed in the mole into a powerful apparatus for digging, by which the animal soon covers itself, and burrows its way under ground. In the wing of the eagle we shall count every bone, and find that although adapted to a new element, they are as powerful to rise in the air, as the fin of the salmon is to strike through the water. The solid hoof of the horse, the cleft foot of the ruminant, the paw of the feline tribe with retractile claws, and the long folding nails of the sloth, are among the many changes in the adjustment of the same chain of bones, which ministers in man to the compound motions of the hand.

Were it my purpose to teach the elements of this subject, I should commence by examining the lowest animals, and trace the gradual approach of the bones of the anterior extremity in their resemblance to the human arm, and also point out the greater variety of uses served by them in the higher animals. But since my pre-

sent object is illustration only, I shall begin with the human arm, and dividing it into the shoulder, arm, and hand, treat each subdivision with a reference to its structure in animals.

OF THE SHOULDER.



In viewing the human figure, or human skele-

ton, in connexion with our present subject, we cannot fail to remark the strength and solidity which belongs to the lower extremities, in contrast with the superior. Not only are the lower limbs proportionably longer and larger in man than in any other animal, but the pelvis is wider, and the obliquity of the neck of the thigh bone greater. The distances of the large processes on the upper ends of the thigh bones (the trochanters,) from the sockets, are also greater than in any of the vertebrata. Altogether, the strength of these bones, the size and prominence of their processes, the great mass of the muscles of the loins and hips, distinguish man from every other animal; they secure to him the upright posture, and give him the perfect freedom of the arms, for purposes of ingenuity and art.

At the head of this chapter is a sketch of the Chimpanzee,* an ape which stands high in the order of quadrumana. Yet we cannot mistake his capacities: that the lower extremities and pelvis, or hips, were never intended to give him the erect posture, or only for a moment. But for

* *Simia troglodytes*, from the coast of Guinea, more human in its form, and more easily domesticated than the ouran-outang. We would do well to consider the abode of these creatures in a state of nature—that they reside in vast forests, extending in impenetrable shade below, whilst above and exposed to the light, there is a scene of verdure and beauty. Such is the home of the monkeys and lemurs, that possess extremities like hands. In

swinging, or for a vigorous pull, who can deny him power in these long and sinewy arms.

The full prominent shoulders, and consequent squareness of the trunk, are equally distinctive of man with the strength of his loins; they indicate a free motion of the hand.

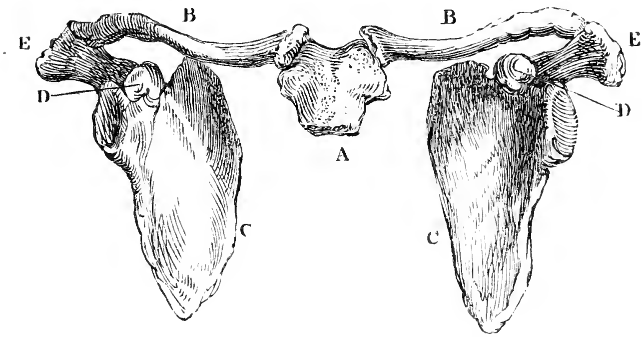
OF THE BONES OF THE SHOULDER.

The bones of the shoulder, being those which give firm attachment to the upper extremity, and which afford origins to the muscles of the arm and fore arm, are simple, if studied in man, or, indeed, in any one genus of animals; but considered in reference to the whole of the vertebral animals, they assume a very extraordinary degree of intricacy. We shall, however, find that in all these different animals, they retain their proper office, notwithstanding the strange variations in the form of the neighbouring parts. In man they lie supported on the ribs, and are directly connected with the great apparatus of respiration; but in other animals we shall see the ribs, as it were, withdrawn, and the bones of the shoulder, or fundamental bones of the

many of them the hinder extremity has a more perfect resemblance to a hand than the anterior; in the Coaita, (p. 20) we see the great toe assuming the characters of a thumb, whilst in the fore paw the thumb is not distinguishable, but is hid in the skin. In short, these paws are not approximations to the hand, corresponding with a higher ingenuity, but are adaptations of the feet to the branches on which the animals climb and walk.

extremity, curiously and mechanically adapted to perform their office without the support of the thorax. We shall not, however, anticipate the difficulties of this subject, but look first upon that which is most familiar and easy, the shoulder of man in comparison with the varieties in the mammalia.

OF THE CLAVICLE.



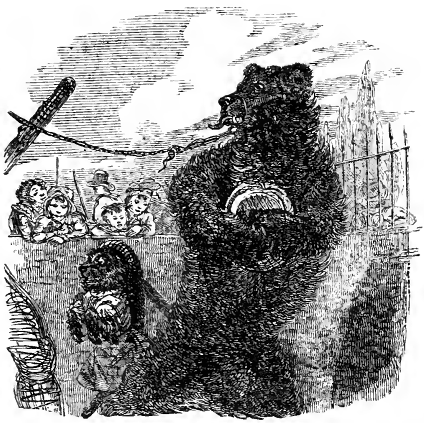
The *clavicle*, or collar bone, runs across from the breast bone to the top of the shoulder. The square form of the chest, and the free exercise of the hand, are very much owing to this bone. It keeps the shoulders apart from the chest, and throws the action of the muscles, proceeding from the ribs, upon the arm bone; which would otherwise be drawn inwards, and contract the upper part of the trunk.

A. Triangular portion of the Sternum, or breast bone. B. B. Clavicles, or collar bones. C. C. Scapulæ, or shoulder blades. D. Coracoid process of the Scapulæ. E. Acromion process of the Scapulæ, forming the tip of the shoulder.

If we examine the motions of the anterior extremity in different animals, and take these as our guide, we shall see why this bone is perfect in some, and entirely wanting in others. Animals which fly, or dig, or climb, as bats, moles, porcupines, squirrels, ant-eaters, armadilloes, and sloths, possess this bone; for in them a lateral or outward motion of the extremity is required. There is also a certain degree of freedom of motion in the anterior extremity of the lion, cat, dog, martin, and bear; they strike with the paw, and rotate the wrist more or less extensively: and they have therefore a clavicle, though an imperfect one. In some of these, even in the lion, the bone which has the place of the clavicle is very imperfect indeed; although attached to the shoulder, it does not extend to the sternum, but lies concealed in the flesh, and is like the mere rudiments of the bone. Yet, however imperfect, it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of motion enjoyed.

When the bear stands up, we perceive by his ungainly attitude and the motion of his paws, that there must be a wide difference in the bones of his upper extremity, from those of the ruminant or solipede. He can take the keeper's hat from his head, and hold it; or can hug an animal to death. The ant-bear especially, as he is deficient in teeth, possesses extraordinary powers of hugging with his great paws; and,

although harmless in disposition, he can nevertheless squeeze his enemy the jaguar to death.



These actions, and the power of climbing, result from the structure of the shoulder, from there being a collar bone, however imperfect.

Although the clavicle is perfect in man, thereby corresponding with the extent and freedom of motion of his hand, yet in the animals which dig or fly, as in the mole and the bat, it is comparatively stronger and longer.

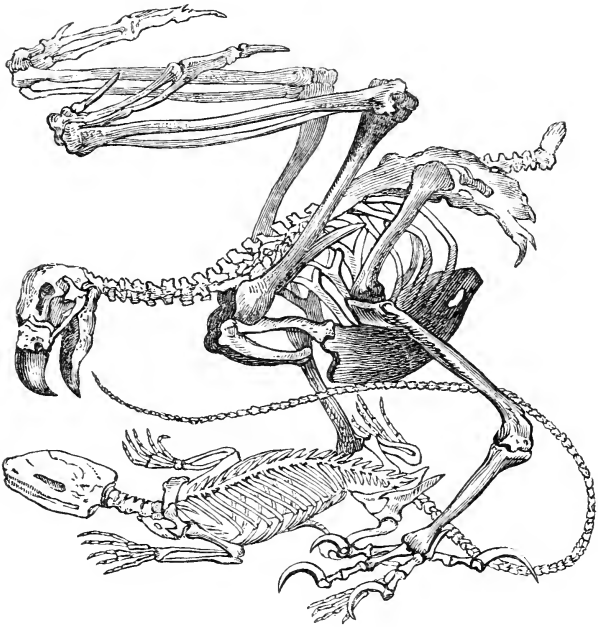
Preposterous as the form of the kangaroo appears, we yet see, even in this animal, a relation preserved between the extremities. He sits upon his strong hind legs and tail, tripod like, with perfect security; having his fore paws free. He has a clavicle, and it is from possessing that bone and the corresponding motions, that he can employ his paws as a means of defence; for with the anterior extremities he will seize the most

powerful dog, and then drawing up his hinder feet, dig his sharp pointed hoofs into his enemy, striking out, and tearing him to pieces. Though possessed of no great speed, therefore, and unprovided with horns, teeth, or claws, but, as we should suppose, totally defenceless, nature has not been negligent of his protection.*

It cannot be better shown, that the function or use of a part determines its form, than by looking to the clavicle and scapula of the bird.

Three bones converge here to the shoulder joint, the scapula, clavicle, and coracoid bone. But neither the scapula nor clavicle has the resemblance which their names would imply. The scapula is the long thin bone, like the blade of a knife: and the clavicles are united at the centre, near the breast bone, to form the furculum, or fork bone, which, in carving, we detach after removing the wings of a fowl. This leaves that stronger portion of bone which is articulated with the breast bone, as a new part: and although it corresponds with the place of the clavicle,

* There is in the form of the kangaroo, and especially in its skeleton, something incongruous, and in contrast with the usual shape of quadrupeds. The head, trunk, and fore paws, appear to be a portion of a smaller animal unnaturally joined to another of greater dimensions and strength. It is not easy to say what are, or what were, the exterior relations corresponding with the very peculiar form of this animal; but the interior anatomy is accommodated, in a most remarkable manner, to the enormous hinder extremities. The subject is taken up in the "Additional Illustrations" in the latter part of the volume, ON THE GENERAL FORM OF THE SKELETON.



yet from bearing an analogy to a process of the irregularly formed scapula, it is called coracoid bone. However, this may be, what we have to admire, is the mode in which the bones are fashioned to strengthen the articulation of the shoulder, and to give extent of surface for the attachment of the muscles moving the wings.

Another peculiarity in birds is, that in flying, they have not an alternate motion of the wings, but their extremities, as we may continue to call them, move together. It is for this reason that the three bones of the shoulder on each side, are joined together to form the fulcrum.

OF THE SCAPULA.

By attending to the scapula, or shoulder-blade, we shall better understand the influence of the bones of the shoulder on the motions and speed of animals. The scapula is that flat triangular bone (see page 50), which lies on the ribs, and is cushioned with muscles. On its anterior angle there is a depressed surface, the glenoid cavity or socket for the arm bone. The scapula shifts and revolves on the ribs with each movement of the arm. To produce these movements, the muscles converge towards it from all sides, from the head, spine, ribs, and breast bone, and by acting in succession, these roll the scapula and toss the arm, in every direction. When the muscles combine in action, they fix the bone; and either raise the ribs in drawing breath, or give firmness to the whole frame of the trunk.

Before remarking further on the influence of the scapulæ on the motions of the arms, I shall give an instance to prove their importance in relation to the function just referred to, that of assisting in drawing in the breath. Hearing that there was a poor lad of fourteen years of age, born without arms, and whose unhappy condition had excited the benevolence of some ladies, I sent for him. I found that indeed he had no arms, but he had clavicles and scapulæ. When I made this boy draw his breath, the shoulders were ele-

vated ; that is to say, the scapulæ were drawn up, they were then fixed, and became the points from which the broad muscles of the chest, diverging towards the ribs, acted in drawing up and expanding the chest in respiration. We would do well to remember this double office of the scapula and its muscles ; that, whilst this bone is the foundation of those of the upper extremity, and never wanting in an animal that has the most remote resemblance to an arm, yet it is the centre also and point d'appui of the muscles of respiration, and acts in that capacity, even when there are no extremities at all.*

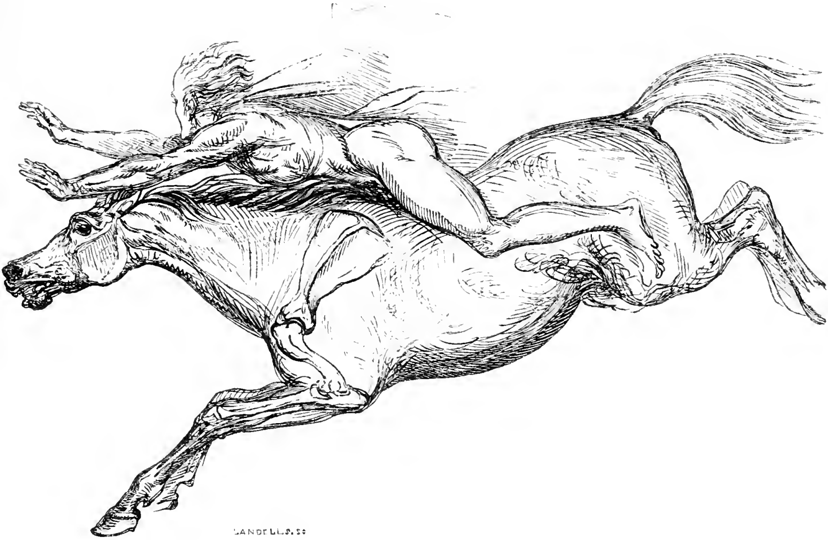
We perceive that it is only in certain classes of animals, that the scapula is joined to the trunk by bone through the medium of a clavicle. A slight depression on the process of the scapula to which the clavicle is attached, when discovered in a fossil state, will therefore declare to the geologist the class to which the animal belonged. For example, there are brought over to this country the bones of the Megatherium, an animal which must have been larger than the elephant ; of the anterior extremity only the scapula has been found ; but on the end of the process, called acromion, of this bone, there is a mark of the attachment of a clavicle. Now

* Some curious facts, illustrative of this office of the muscles of the arm situated on the chest, are stated in the author's paper on the VOICE; in the Philosophical Transactions. 1832.

this points out the whole constitution of the extremity; that it enjoyed perfect freedom of motion. Other circumstances will declare whether that extensive motion was bestowed to enable the animal to dig with its huge claws, like some of the edentata, or to strike out like the feline tribe.

Some interest is attached to the position of the scapula, in the horse. In him, as well as in other quadrupeds, with the exceptions that I have pointed out, there is no clavicle. The connection between the anterior extremity and the trunk is solely through muscles: and the muscle called serratus magnus, which is large in man, is particularly powerful in the horse; for the weight of the trunk hangs almost exclusively upon this muscle. But the speed of the horse, as in most quadrupeds, results from the strength of the loins and hinder extremities; it is the action of the muscles situated there, that propel him forwards, in the gallop or at the leap. We accordingly perceive that if the anterior extremities had been joined to the trunk firmly, and by bone, they could not have withstood the shock from the descent of the whole weight of the animal when thrown forwards. Even though the fore legs had been formed as powerful as the posterior extremities, they would have suffered fracture or dislocation. We cannot but admire, therefore, this provision in all quadrupeds whose

speed is great, and whose spring is extensive, for diminishing the shock of descending, and giving an elasticity to the anterior extremities.



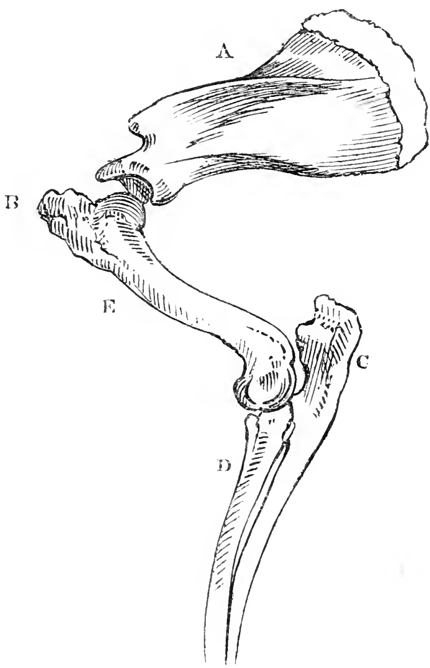
If we observe the bones of the anterior extremity of the horse, we shall perceive that the scapula is oblique to the chest; the humerus oblique to the scapula; and the bones of the fore arm at an angle with the humerus. Were these bones connected in a straight line, end to end, the shock of alighting would be conveyed as through a solid column; and the bones of the foot, or the joints, would suffer from the concussion. When the rider is thrown forwards on his hands, and more certainly when he is pitched on his

shoulder, the collar bone is broken; because in man, this bone forms the link of connection between the shoulder and the trunk, and it accordingly receives the whole shock. Now the same would happen in the horse, the stag, and all quadrupeds of great strength and swiftness, were not the scapulæ sustained by muscles, in place of bone; and did not the bones recoil and fold up.

The horse-jockey runs his hand down the horse's neck, in a knowing way, and says, "this horse has got a heavy shoulder; he is a slow horse!" He may be right, and yet not understand the matter. It is not possible that the shoulder can be too much loaded with muscle, for muscle is the source of motion, and bestows power. What the jockey feels, and forms his judgment on, is the abrupt transition from the neck to the shoulder; while, in a horse for the turf, there ought to be a smooth undulating surface. This abruptness, or prominence of the shoulder, is a consequence of the upright position of the scapula; the sloping and light shoulder results from its obliquity. An upright shoulder is therefore the mark of a stumbling horse: the scapula does not revolve easily, to throw forward the foot.

Much of the strength, if not the freedom and rapidity of motion of a limb, will depend on the angle at which the bones lie to each other; for,

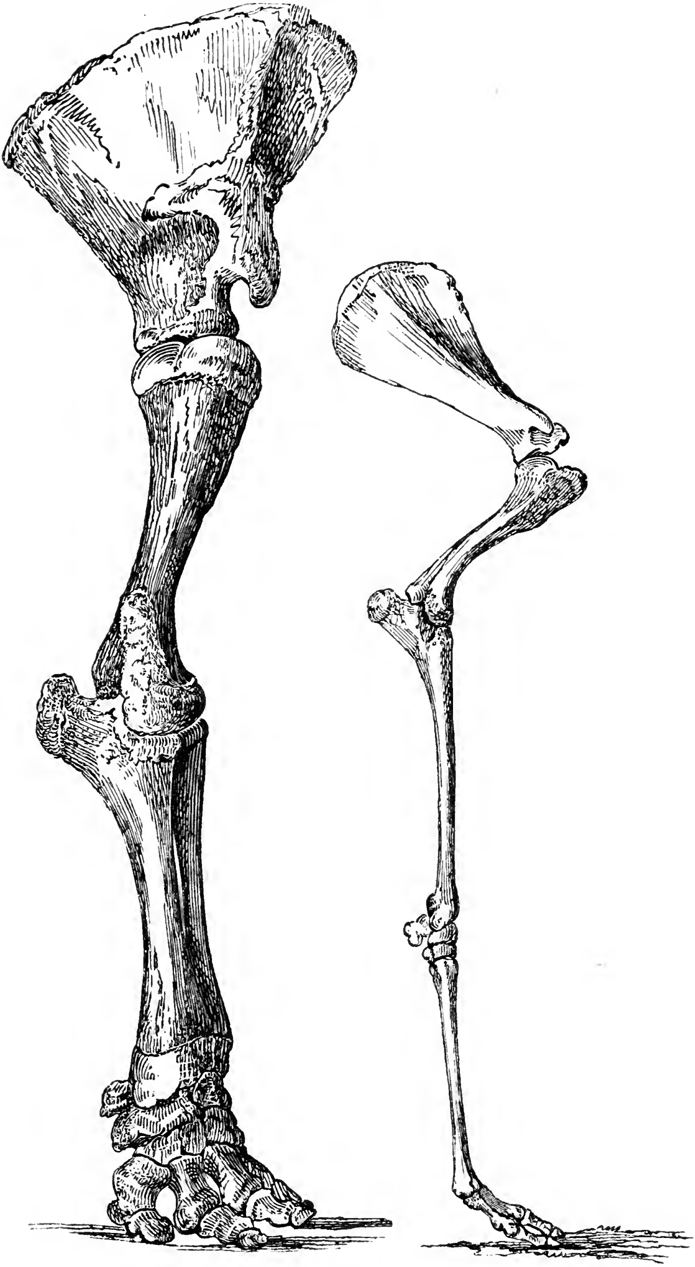
this mainly affects the insertion, and, consequently, the power of the muscles. We know, and may every moment feel, that when the arm is extended, we possess little power in bending it; but in proportion as we bend it, the power is increased. This is owing to the change in the direction of the force acting upon the bone; or,



in other words, to the tendon of the muscle becoming more perpendicular to the lever. A

A. Scapula. E. Humerus, or arm-bone. B. Tuberosity of the Humerus. C. Olecranon, or projection of the Ulna. D. Radius.

scapula which inclines obliquely backwards, increases the angle at which the humerus, or arm bone lies with reference to it: and, consequently the muscles which pass from it to the arm bone, will act with greater effect, from being inserted into that bone more nearly at a right angle. We have only to turn to the skeleton of the elephant, the ox, the elk, or the stag, to see the confirmation of this principle. When the scapula lies obliquely on the chest, the serratus muscle, which passes from the ribs to its uppermost part, has more power in rolling it. This direction of the scapula causes it to lie at right angles with the humerus; and accordingly the muscles which are attached to the latter, (at B.) act with more effect. And on the same principle, by the oblique position of the humerus, and, consequently, its obliquity in reference to the radius and ulna, the two bones of the fore-arm, the power of the muscle inserted (at C.) into the olecranon, is increased. On the whole, both power and elasticity are gained by this position of the superior bones of the fore-leg. It gives to the animal that springs, a larger stretch in throwing himself forwards, and security, in a soft descent of his weight. A man, standing upright, cannot leap or start off at once; he must first sink down, and bring the bones of his extremities to an angle. But the antelope, or other timid animals of the class, can leap at

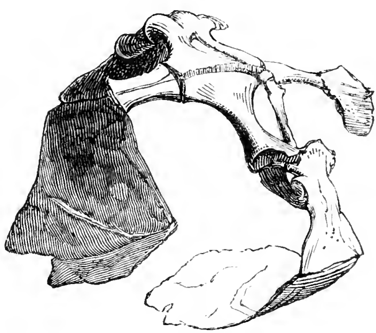


once, or start off in their course without preparation: another advantage of the oblique position of their bones when at rest.

These sketches with the pen are from the skeletons of the elephant and the camel: and it is obvious that the leg of the former is built for the purpose of sustaining the huge bulk of the animal, whilst in the camel there is a perfect contrast. Were we to compare the bones of the larger animal, with any style of architecture, it would be with the Egyptian, or rather from their huge and shapeless form, and from being piled over each other, as if destined more to sustain weight, than to permit motion, they might be likened to the unwrought masonry in the Cyclopian walls of some ancient city.

We further perceive, from the comparison of these sketches, that if the humerus be placed obliquely, it must necessarily be short; otherwise the leg would be thrown too far back, making the head and neck project inordinately. It is one of the "points" of a horse to have the humerus short. And not only have all animals of speed this character, but birds of long flight, as the swallow, have the humerus short. This is owing, I think, to another circumstance, that the shorter the humerus, the quicker will be the extension of the wing: for as the further extremity of the bone when short, will move in a lesser circle, the gyration will be more rapid.

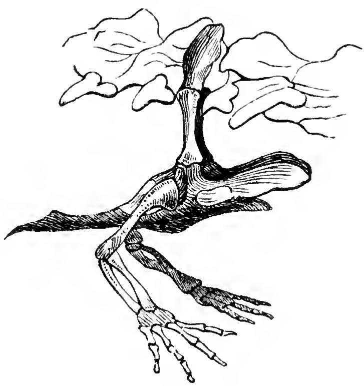
If we continue to take the bones of the shoulder as a distinct subject, and trace them comparatively, we shall be led to notice some very curious modifications in them. There are two objects, we have already seen, to be attained in the construction of these bones. In man, and mammalia, besides forming the basis for the other bones of the extremity, they constitute an important part of the organ of respiration, and conform to the structure of the thorax. But we shall find that in some animals, this latter function is in a manner withdrawn from them; the scapulæ and the clavicles are left without the support of the ribs. These bones, therefore, in order to form the shoulder, require additional carpentry; or they must be laid together on a new principle. In the batrachian order,* for example in the



frog, the mechanism of respiration is altogether

* See the Appendix under the 3rd Class of Vertebrata, *Reptiles*.

different from what it is in the mammalia: and the thorax, as constituted of ribs, has disappeared. Accordingly, we find that the bones of the shoulder are on a new model; they form a broad and flat circle,* sufficient to give secure attachment to the extremity, and affording a large space for the lodgement of the muscles which move the arm. Perhaps the best example of this structure is in the siren and proteus; where the ribs are reduced to a very few imperfect processes, attached to the anterior dorsal vertebræ; and where the bones of the shoulder, being deprived, accordingly, of all support from the thorax, depend upon themselves for security. Here the bones corresponding to the sternum,



clavicles, and scapulæ, are found clinging to the

* The Scapula, Clavicle, Sternum, and Coracoid bone may be recognised in the figure of the bones of a Frog, in the preceding page.

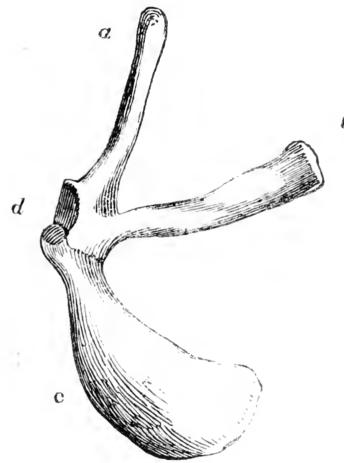
spine, and forming a circle, like the pelvis,* to the lateral parts of which the arm bones are articulated.

In the chelonian order,† the tortoises, we see another design accomplished, by a new adjustment, or new mode of union of these bones; and the change is owing to a very curious circumstance. The spine and ribs of these animals are like rafters placed under the strong shell which forms their covering or carapace; and being united to this shell, they are consequently external to the bones of the shoulder. The scapulæ and clavicles are thus within the thorax, instead of being outside and supported by it. Hence, as they have nothing upon which they can rest, neither ribs nor spine, in order to afford fixed points to which the extremities may be attached, they must necessarily fall together, and form a circle. It would, indeed, be strange if, when thus joined for the purpose of giving attachment to the humerus, and in circumstances, as we may express it, so very new, they preserved any resemblance to the forms which we have been contemplating in the higher animals. In the figure,‡ in the next page, the bones of the shoulder of the

* The pelvis is the circle of bones on which the spine or backbone rests, and in which are the sockets for the heads of the thigh bones.

† See again the Appendix, iii. Class of Vertebrata.

‡ A. Scapula. B. Acromion process. C. Coracoid bone. D. Glenoid cavity.



turtle are represented; and it is readily perceived how much they have changed both their shape and their offices. That part which is most like a scapula in shape, lies on the fore part instead of the back part; and the bones which hold the shoulders apart, abut upon the spine, instead of upon the sternum. Hence it appears idle to describe these bones under the old denominations, or such as are applicable to their condition in the higher animals.

In fishes, although the apparatus of respiration has undergone another entire change, and there are no proper ribs, the bones which give attachment to the pectoral fin, are still called the bones of the shoulder. That which is named scapular appendage or arch, is, in fact, attached to the

bones of the head, instead of to the ribs or spine. So that the structure corresponding with the shoulder consists of a circle of bones, which, we may say, seeks security of attachment by approaching the more solid part, the head, in defect of a firm foundation in the thorax.

Thus it has been shown that the bones which form the shoulder joint, and give a foundation to the anterior extremity, are submitted to a new modelling in correspondence with every variety in the apparatus of respiration; and still they maintain their pristine office.

The naturalist will not be surprised on finding in the shoulder apparatus of the ornithorhynchus paradoxus, an extraordinary intricacy: since the whole frame and organs of this animal imply that it is intermediate between mammalia and birds; for which reason it has been placed in the list of edentata. This animal only affords another instance of the changes which the bones of the shoulder undergo with every new office, that they may correspond with the motions of the extremity; whether it be to support the weight in running, or to give freedom to the arm, or to provide for flying, or to enable the animal either to creep or to swim.

Unprofitable as the enquiry may seem, there is no other way for the geologist to distinguish the genera of the extinct and strangely formed oviparous reptiles imbedded in the secondary

strata, than by studying in the recent species, the minute processes and varying characters of these bones. In the ichthyosaurus, and plesiosaurus, the inhabitants of a former world, there is a considerable deviation from the general type of the bones of the arm and hand, as compared with the same parts in the frog and tortoise; but the bones of the shoulder, we should say, if strength were the object, are formed with a greater degree of perfection in these extinct reptiles. The explanation of this is, that the ribs and sterno-costal arches, constituting the thorax, are more perfect in them than in the chelonian and batrachian orders; whence the bones of the shoulder are situated externally, and resemble those of the crocodile. Yet, notwithstanding this superiority, the ribs were obviously not strong enough to sustain the powerful action of the muscles of the anterior extremities, or paddles; accordingly, the bones, which by a kind of license we continue to call clavicle, omoplate or scapula, and coracoid, though strangely deviating from the original forms and connexions, constitute a texture of considerable strength, which perfects the anterior part of the trunk, and gives attachment and lodgement to the powerful muscles of the paddle.

But it does not appear that naturalists have hit upon the right explanation of the peculiar structure, and curious varieties of these bones,

in the class of reptiles. Why is the apparatus of respiration so totally changed in these animals? They are cold blooded animals; they require to respire less frequently than other creatures, and they remain long under the water. I conceive that the peculiarity in their mode of respiration corresponds with this property. Hence their vesicular lungs; their mode of swallowing the air, instead of inhaling it; and hence, especially, their power of compressing the body and expelling the air. It is this provision for emptying the lungs, I imagine, which enables reptiles to go under the water and crawl upon the bottom. Had they possessed the lungs of warm blooded animals, which are compressible only in a slight degree, their capacity of remaining under water would have been of no use: when they dived, they would have had to struggle against their own buoyancy, like a man, or any of the mammalia. The girdle of bones of the shoulder is constituted, therefore, with a certain relation to the peculiar action of respiration; inasmuch as the pliancy of the thorax is provided in order that the vesicular lungs may be easily compressed, and the specific weight diminished. The facility which the absence of ribs, in the batrachian order, affords for compressing the lungs extended through the abdomen, and the extreme weakness and pliancy of the ribs in the saurians, must be, as I apprehend, peculiarities adapted to the same end.

OF THE HUMERUS, OR ARM BONE.

The demonstration of this bone need not be so dry a matter of detail as the anatomist makes it. We may deduce from its form that curious relation of parts, which has been so successfully employed by Paley to prove design; and from which the genius of Baron Cuvier has brought out some of the finest examples of inductive reasoning.

In looking to the head of this bone in the human skeleton, (see the fig. page 50,) we observe its great hemispherical surface for articulating with the glenoid cavity or socket of the scapula; and we see that the two tubercles for the insertion of the muscles, near the joint, are depressed, and do not interfere with the revolving of the humerus, by striking against the edges of the socket. Such appearances alone are sufficient to show that all the motions of the arm are free.

To give assurance of this, and to illustrate how the form of the shoulder points to the structure of the whole arm, suppose that the geologist has picked up this bone in interesting circumstances. To what animal does it belong? The globular form

of the articulating surface, and the very slight projection of the tubercles, evince a latitude and extent of motion. Now, freedom of motion in the shoulder implies freedom also in the extremity or paw, and a power of rotation in the bones of the wrist. Accordingly, we direct the eye to that part of the bone which gives origin to the muscles for turning the wrist, (the *Supinator muscles*) ; and the prominence and length of the ridge or crest situated on the lower and outer side, at once prove the strength of these muscles, and consequently that the paw had a free motion.

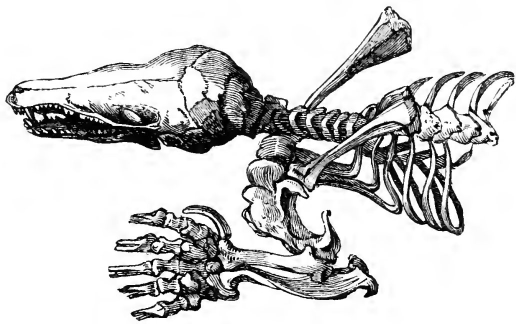
Therefore, on finding the humerus thus characterized, we conclude that it belonged to an animal with sharp moveable claws ; that, in all probability, it is the remains of a bear.

But, suppose that the upper head of the bone has a different character: that the tubercles

project, so as to limit the motion in every direction but one, and that the articulating surface is less regularly convex. On inspecting the lower extremity of such a bone, we shall perceive that the grooves, into which the bones of the fore-arm are socketed, are hollowed out so deeply, that the joint could only have the motion of a simple hinge; and neither the form of the articulating surface, (which is here called trochlea,) nor the crest or spine above noticed on the outside, will present any signs of one bone of the fore-arm having rotated on the other. We have, therefore, got the bone of an herbivorous quadruped, either with a solid or with a cloven foot.

In the bat and mole perhaps the best examples are seen of the bones of the extremity being moulded to correspond with the condition of the animal. The mole is fitted, by means of its anterior extremities, to plough its way under ground. The bat has the same system of bones: but they are adapted to form a wing, for raising the animal in the atmosphere, and with a provision for its clinging to the wall, although not to bear upon it. We recognise in both these animals, every bone of the upper extremity; but how very differently formed and joined! In the mole, the sternum or breast bone, and the clavicle are remarkably large: the scapula, or shoulder blade, assumes the form of a high lever: the humerus is thick and short, and has

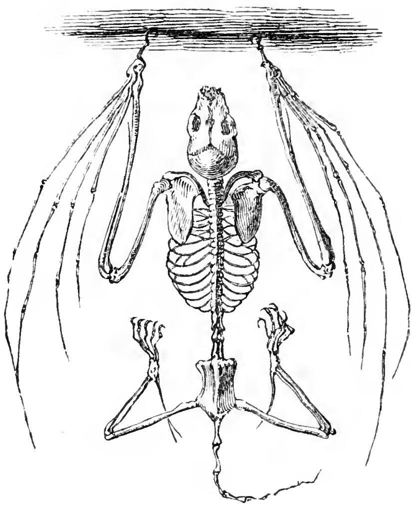
such prominent spines for the attachment of muscles, as to indicate great power. The spines which give origin to the muscles of rotation, project in an extraordinary manner; and the hand is large, flat, and so turned that it may shove the earth aside like a ploughshare.*



There can be no greater contrast to these bones of the mole than is presented in the skeleton of the bat. In this animal the bones are light and delicate; and whilst they are all

* The snout may vary in its internal structure with new offices. Naturalists say that there is a new "element" in the pig's nose: and it has, in fact, two bones which admit of motion, whilst they give more strength in digging the ground. As moles plough the earth with their snouts: they have likewise these bones, and their head is shaped like a wedge, to assist in burrowing and throwing aside the earth. The conformation of the head, and the strength of its bones, and the new adjustment of a muscle, (the *Platisma Myoides*) which is cutaneous in other animals, to assist in moving the head, are among the most curious changes of common parts for enabling them to perform new offices. See again the "Additional Illustrations."

marvellously extended, the phalanges or the rows of bones of the fingers, are elongated so as hardly to be recognised, obviously for the pur-



pose of sustaining the membraneous web, and to form a wing.

Contemplating this extraordinary application of the bones of the upper extremity in the bat, we might be led to say, on comparing it with the wing of a bird, that it was an awkward attempt —" a failure." But before giving expression to such an opinion, we must understand the objects required in this construction. The wing of the bat is not intended merely for flight: it is so formed that while it can sustain the animal in flying, it shall be capable also of receiving a

new sensation on its surface, or sensations of such an exquisite degree as almost to constitute a new sense. On the fine web of the bat's wing numerous nerves are distributed; the use of which is to enable the animal, during the obscurity of night, when both eyes and ears fail, to avoid objects in its flight. Could the wing of a bird, covered with feathers, do this? Here then we have another example of the necessity of taking every circumstance into consideration before presuming to criticise the ways of nature. It is a lesson of humility.*

In the next page we have a sketch of the arm bones of the Ant-eater,† to shew once more the correspondence maintained throughout all the parts of an extremity. We observe these ex-

* Besides the adaptation of the bat for flight, by the adjustment of the bones of its arm, this animal has a series of cells situated under its skin. I know not, however, whether I am authorized to say that these are analogous to the air-cells of birds, and serve to make the bat specifically lighter or not. They extend over the breast, and under the axillæ in some bats; and are filled by an orifice which communicates with the pharynx.

We have adverted to the provisions in the bones of the shoulder of the bird, to give firmness to this joint, seeing that it is the centre of motion for the wing. Now, although the bat has not the same arrangement of bones, yet the clavicles are remarkably strengthened: and the articulation of the arm bone upon the shoulder blade is guarded by processes in such a manner that the motion of this joint is extremely limited.

† Tamandua, from South America.

traordinary spines standing off from the humerus. Now these indicate the power of the muscles attached to the bone; for, as I have said before, whether we examine the human body, or the forms of the bones in the lower animals, the distinctness with which the spines and processes are marked, declares the strength of the muscles. It is particularly pleasing to notice here the correspondence between the humerus and all the other bones,—how large the scapula is, in the first place, and how it has a double spine, with great processes: how remarkably the ulna projects at the olecranon or elbow, while the radius is still free for rotating: but above all, we cannot fail to observe in the developement of one grand metacarpal bone and its corresponding phalanges, to the last of which a strong claw is attached, a most efficient instrument for scratching and turning aside an ant-hill. The whole, therefore, is an example of the relation of the particular parts of the extremity to one another; and were it our

business, it would be easy to show that as there is a correspondence among the bones of the arm, so is there a more universal relation between those of the whole skeleton. As the structure of the bones declares the provision of the extremity to be for digging into ant-hills, so we shall not be disappointed in our expectation of finding that the animal has a projecting muzzle unarmed with teeth, and a long tongue provided with a glutinous secretion, to lick up the emmets that have been disturbed by its scratching.

In the skeleton of the cape-mole, we may see, from the projection of the acromion scapulæ, and a remarkable process in the middle of the humerus, that there is a provision for the rotation of the arm, which implies burrowing. But the apparatus is by no means so perfect as in the common mole, so that we may infer that the cape-mole digs in a softer soil, whilst the possession of gnawing teeth indicates that it lives on roots .

In Birds there is altogether a new condition of the osseous system, as there is a new element to contend with. The very peculiar form and structure of their skeleton may be thus accounted for. First, it is necessary that birds, as they are buoyed in the air, should be specifically lighter. Secondly, the circumference of their thorax must be extended, and the motions of their ribs limited, that the muscles of the wings

may have sufficient space and firmness for their attachment. Both these objects are attained by a modification of the apparatus for breathing. The lungs are highly vascular and spongy, but they are not capable of being distended with air. The air is drawn through their substance, passing, by means of numerous orifices, into the large cavity common to the chest and abdomen; so that whilst the great office of decarbonization of the blood is securely performed, advantage is taken to let the air, warmed and rarefied by the high temperature of their bodies, into all the cavities, even into those of the bones.

From what was said, in the introductory chapter, of the weight of the body being a necessary concomitant of muscular strength, we see why the lightness of a bird, as well as the conformation of its skeleton, may be a reason for its walking badly. On the other hand, in observing how this lightness is adapted for flight, it is remarkable what a small addition to the weight of a bird will prevent its rising on the wing. If the griffon-vulture be frightened after his repast, he must disgorge, before he can fly; and so with the condor, if he be found in the same circumstances, he is taken by the Indians, like a quadruped, by throwing the lasso over his neck.*

As every one must have observed, the breast-

* The subject is continued in the "Additional Illustrations."

bone of birds extends the whole length of the body, so as to cover the great cavity common to the chest and abdomen, into which the air is admitted. Now it follows from this extension of the breast-bone, that a lesser degree of motion suffices to respiration; accordingly, a greater surface, necessary for the lodgement and attachment of the muscles of the wings, is obtained, whilst that surface is less disturbed by the action of breathing, and is more steady. Another peculiarity of the skeleton of the bird is, that the vertebræ of the back, instead of being moveable on each other, are consolidated: an additional proof, if any were now necessary, that the whole system of bones conforms to that of the extremities; because, to give effect to the action of the muscles of the wings, it is necessary that all the bones of the trunk to which they are attached should be united firmly together.*

From the vertebræ of the back being thus fixed in birds, and the pelvis reaching high, no motion can take place in the body; indeed, if there were any mobility in this part of the spine, it would be interrupted by the sternum, or breast-bone. We cannot but admire, therefore, the structure of the neck and head, and how the length and pliability of the vertebræ of the neck, not only give to the bill the extent of

* The ostrich and cassowary, which are rather runners than fliers, have the spine loose.

motion and office of a hand, but become a substitution for the loss of flexibility in the body, by enabling the bird to preserve its balance, in standing, running, or flying. Is it not curious to observe how the whole skeleton is adapted to this one object, the power of the wings!

Whilst the ostrich and other "runners" have no keel in their breast-bone, birds of passage are recognisable, on dissection, by the depth of this ridge of the sternum. The reason is that the angular space, formed by this process and the body of the bone, affords lodgement for the pectoral muscle, the powerful muscle of the wing. In this sketch of the dissection of the swallow,

there is a curious resemblance to the human arm; and we cannot fail to observe that the pectoral muscle constitutes the greater part of the bulk of the body.* And here we see the correspondence between the strength of this muscle and the rate of flying of the swallow, which is a mile in a minute, for ten hours every day, or six hundred miles a day.† If it be true that birds, when migrating, require a wind that blows against them,‡ it implies an extraordinary power, as well as continuance of muscular exertion.

We thus see how nature completes her work when it is intended that the animal shall rise buoyant and powerful in the air:—the whole texture of the frame is altered, and made light in a manner consistent with strength. We see

* Borelli makes the pectoral muscles of a bird exceed in weight all the other muscles taken together; whilst he calculates that the pectoral muscles of man are but a seventieth part of the whole mass of the muscles.

† Mr. White says truly, that the swift lives on the wing; it eats, drinks, and collects materials for its nest while flying, and never rests but during darkness.

No bird equals the humming-bird in its powers of flight, and accordingly, it has a broader sternum, and a greater prominence of keel, in proportion to its size, than any other bird.

It may be mentioned, that in the bat a very distinct ridge is developed, corresponding with the keel of the bird.

‡ It is possible that the wind blowing near the ground in one direction may be attended with the motion of a higher stratum of the atmosphere in a contrary direction, and that the idea of migrating birds flying against the wind may have arisen from this mistake.

also how the mechanism of the anterior extremity is changed, and the muscles of the trunk differently directed. But we are tempted to examine those means, which we would almost say are more awkwardly suited for their purpose, where the system of bones and muscles peculiar to the quadruped is preserved, while the animal has still the power of launching into the air. We have already noticed how the structure of the bat is adapted to flight; but there are other animals differing more widely than it from birds, which enjoy this function though in a lesser degree. For example, the flying squirrel (Pteromys Volucella), being chased to the end of the bough, spreads out its mantle, which reaches along both its sides from the anterior to the posterior extremity, and drops in the air; and it is met, during its descent, with such a resistance from its extended skin and its bushy tail, that it can direct its flight obliquely downwards, and even turn in the air, without there being any adaptation of the anterior extremity. Among reptiles, there is a provision of the same kind in the Draco fimbriatus; which, after creeping to a height, can drop safely to the ground, under the protection of a sort of parachute, formed by its extended skin. This is not an inapt illustration; the phalanges of the fingers are not here used to extend the web; but the ribs, which are unnecessary in this animal for breathing, are prolonged in a remarkable manner,

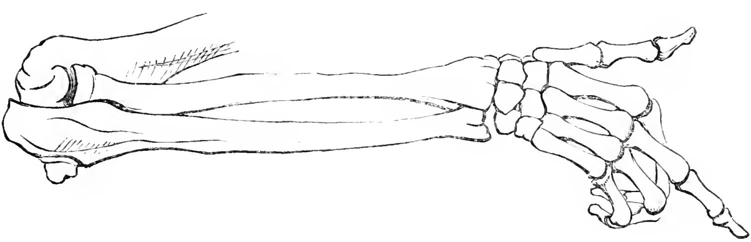
like the whale-bones of an umbrella, and upon them the skin is expanded.

But this brings us to a very curious subject,—the condition of some of those Saurian reptiles, the remains of which are found only in a fossil state, in the lias or what are termed the ancient strata of the Jura. The Pterodactyle of Cuvier is an animal which seems to confound all our notions of system. Its mouth was like the long bill of a bird, and its flexible neck corresponded; but it had teeth in its jaws like those of a crocodile. It had the bones of the anterior extremity prolonged, and fashioned somewhat like those in the wing of a bird; but it could not have had feathers, as it had not a proper bill. We see no creature with feathers, that has not a bill with which to dress and prin them. Nor did this extremity resemble that of a bat in its structure: instead of the phalanges or rows of bones of all the fingers being equally prolonged, as in the bat, the second finger only was extended to an extraordinary length, whilst the third, fourth, and fifth had the length and articulation of those of a quadruped, and they were terminated with sharp nails, corresponding with the pointed teeth. The extended metacarpal bone and phalanges reached to double the whole length of the animal, and the conjecture is, that a membrane was extended upon them resembling that of the Draco fimbriatus. In the imperfect specimens which we have to found our reasoning upon, we

cannot discover, either in the height of the pelvis, the strength of the vertebræ of the back, or the expansion of the sternum, a provision for the attachment of muscles commensurate with the extent of the supposed wing. The humerus, and the bones which we presume to be the scapula and coracoid, bear some correspondence to the extent of the wing; but the extraordinary circumstance of all is the size and strength of the bones of the jaw and vertebræ of the neck, compared with the smallness of the body, and the extreme delicacy of the ribs; which make it, altogether, the thing the most incomprehensible in nature.

OF THE RADIUS AND ULNA.

The easy motion of the hand, we might imagine to result from the structure of the hand itself; but, on the contrary, the movements which appear to belong to it, are divided among all the bones of the extremity.*



* In this sketch, the upper bone of the fore-arm is the radius, and in revolving on the lower bone, the ulna, it carries the hand with it.

The head of the humerus is rotatory on the scapula, as when making the guards in fencing; but the easier and finer rolling of the wrist is accomplished by the motion of the radius on the ulna.

The ulna has a hooked process, the olecranon, or projecting bone of the elbow, which catches round the lower end of the humerus or arm bone, (this articulating portion is called trochlea), and forms with it a hinge joint. The radius, again, at the elbow, has a small, neat, round head, which is bound to the ulna by ligaments, as a spindle is held in the bush; and it has a depression with a polished surface for revolving on the condyle of the humerus. This bone turns on its long axis, rolling upon the ulna both at the elbow and wrist-joint; and, as it turns, it carries the hand with it, because the hand is strictly attached to its lower head alone. This rolling, is what is termed pronation and supination.

Such a motion would be useless, and a source of weakness in an animal that had a solid hoof. Accordingly, in the horse, these bones are united together, and consolidated in the position of pronation.

But let us extend our views before we take the particular instance. There is indeed something so highly interesting in the conformation of the whole skeleton of an animal, and the

adaptation of any one part to all the other parts, that we must not let our reader remain ignorant of the facts, or of the important conclusions drawn from them. What we have to state has been the result of the studies of many naturalists; but although they have laboured, as it were, in their own department of comparative anatomy, they have failed to seize upon it with the privilege of genius, and to handle it in the masterly manner of Cuvier.

Suppose a man ignorant of anatomy to pick up a bone in an unexplored country, he learns nothing, except that some animal has lived and died there; but the anatomist can, by that single bone, estimate not merely the size of the animal, as well as if he saw the print of its foot, but the form and joints of the skeleton, the structure of its jaws and teeth, the nature of its food, and its internal economy. This, to one ignorant of the subject, must appear wonderful, but it is after this manner that the anatomist proceeds. Let us suppose that he has taken up that portion of bone in the limb of the quadruped, which corresponds to the human radius; and that he finds that the form of the bone does not admit of free motion in various directions, like the paw of the carnivorous creature. It is obvious, by the structure of the part, that the limb must have been merely for supporting the animal, and for progression, and not

for seizing prey. This leads him to the fact that there were no bones resembling those of the hand and fingers, or those of the claws of the tiger; for the motions which that conformation of bones permits in the paw, would be useless, without the rotation of the wrist: he concludes, therefore, that these bones were formed in one mass, like the cannon bone, pastern bones, and coffin bone of the horse's foot.*

The motion of the foot of a hoofed animal being limited to flexion and extension, implies a restrained motion in the shoulder joint, and the absence of a collar bone; and thus the naturalist, from the specimen in his hand, acquires a perfect notion of all the bones of the anterior extremity! The motions of the extremities imply a condition of the vertebral column which unites them. Each bone of the spine will have that form which permits the bounding of the stag, or the galloping of the horse; but it will not have the kind of articulation which admits of the turning or writhing of the spine, as in the leopard or the tiger.

And now he comes to the head:—the pointed, cutting teeth of a carnivorous animal to rend prey would be useless, unless there were claws for holding it, and a mobility of the extremities

* These are solid bones, where it is difficult to recognise any resemblance to the metacarpus and bones of the fingers; yet comparative anatomy proves that they are analogous.

like that of the hand, for grasping it. He considers, therefore, that the front teeth must have been for browsing, and the back teeth for grinding. But the socketing of the teeth in the jaws requires a peculiar shape of these bones, and the muscles which move them must also be peculiar; in short, he forms a conception of the figure of the skull. From this point he may set out anew, for by the form of the teeth, he may ascertain the nature of the stomach, the length of the intestines, and all the peculiarities which mark a vegetable feeder.

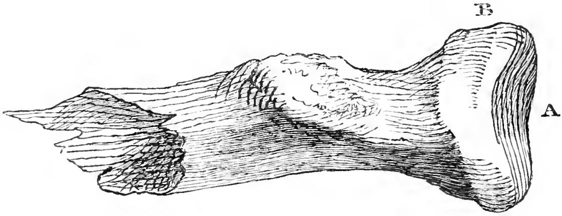
Thus the whole parts of the animal system are so connected with one another, that from one single bone or fragment of bone, be it of the jaw, or of the spine, or of the extremity, a really accurate conception of the shape, motions, and habits of the animal, may be formed.

It will readily be understood that by the same process of reasoning we may ascertain, from a small portion of a skeleton, the existence of a carnivorous animal, or of a fowl, or of a bat, or of a lizard, or of a fish; and what a conviction is here brought home to us, of the extent of that plan, which adapts the members of every creature to their proper office, and yet exhibits one system pervading the whole range of animated beings, whose motions are conducted by the operation of muscles and bones!

After all, this is but a part of the wonders

disclosed through the knowledge of a thing so despised as a fragment of bone. It carries us into another science. The knowledge of the skeleton not only teaches us the classification of creatures now alive, but affords proofs of the former existence of animated beings which are not now to be found on the surface of the earth. We are thus led to an unexpected conclusion from such premises. Not merely do we learn that an individual animal, or race of animals, now extinct, existed at that distant period: but even the changes which the globe has undergone in times before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

To return to our particular subject, we readily comprehend how it happens that if the geologist should find the nearer head of the radius, resembling this sketch, and see in the extremity of it



a smooth depression (A), where it bears against the humerus, and a polished circle (B) where it turns on the cavity of the ulna,—he would

say,—this animal had a paw—it had a motion at the wrist, which implies claws. But claws may belong to two species of animals: to the feline, which possesses sharp carnivorous teeth, or to animals without either canine or cutting teeth, the Edentata. If he should find the lower extremity of this same bone, and observe on it spines and grooves for distinct tendons to disperse to the phalanges, instead of running to be inserted into a single bone, he would conclude that there must have been moveable claws—that the bone must have belonged to a carnivorous animal; and he would seek for canine teeth of corresponding size.

THE LAST DIVISION OF THE BONES OF THE ARM.

In the human hand, the bones of the wrist (carpus) are eight in number; and they are so closely connected that they form a sort of ball, which moves on the end of the radius. Beyond these, and towards the fingers, forming the palm of the hand, are the metacarpal bones, which diverge at their further extremities, and give support to the bones of the fingers. The thumb has no metacarpal bone, and is directly articulated with the carpus or wrist. There are thus in the hand twenty-nine bones, from the mecha-

nism of which result strength, mobility and elasticity.

Lovers of system (I do not use the term disparagingly) delight to trace the gradual subtraction of the bones of the hand. Thus, looking to the hand of man, they see the thumb fully formed. In the simiæ they find it exceedingly small; in one of them, the spider-monkey, it has disappeared, and the four fingers are sufficient, with hardly the rudiments of a thumb. In some of the tardigrade animals, as we have seen (in page 32), there are only three metacarpal bones with three fingers. In the horse, the cannon bone may be shewn to consist of two metacarpal bones. Indeed, we might go further and instance the wing of the bird. To me, this appears to be losing the sense, in the love of system. There is no regular gradation, but, as I have often to repeat, a variety most curiously adapting the same system of parts to every necessary purpose.

In a comparative view of these bones, we are led more particularly to take notice of the foot of the horse. It is universally admitted to be of beautiful design, and calculated for strength and elasticity, and especially provided against concussion.

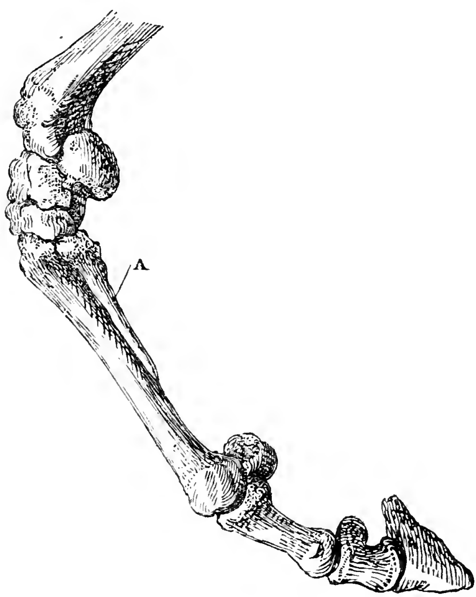
The bones of the fore-leg of the horse become firmer as we trace them downwards. The two bones corresponding with those of the fore-arm,

are braced together and consolidated; and the motion at the elbow-joint is limited to flexion and extension. The carpus, forming what by a sort of license is called the knee, is also newly modelled; but the metacarpal bones and phalanges of the fingers are totally changed, and can hardly be recognised. When we look in front, instead of the four metacarpal bones we see one strong bone, the cannon bone; and posterior to this, we find two lesser bones, called splint bones. The heads of these lesser bones enter into the knee-joint (or properly the wrist-joint); but at their lower ends they diminish gradually, and they are held by an elastic ligamentous attachment to the sides of the cannon bone.

I have some hesitation in admitting the correctness of the opinion of veterinary surgeons on this curious piece of mechanism. They imagine that these moveable splint bones, by playing up and down as the foot is alternately raised and pressed to the ground, bestow elasticity and prevent concussion. The fact certainly is that by over action this part becomes inflamed, and the extremities preternaturally joined by bone to the greater metacarpal or cannon bone; and that this, which is called a splint, is a cause of lameness.

I suspect, rather, that in the perfect state of the joint, these lesser metacarpal bones act as a

spring to throw out the foot, when it is raised and the knee-joint bent. If we admit that it is the quickness in the extension of this joint on which the rate of motion must principally depend, it will not escape observation, that in the bent position of the knee, the extensor tendons have very little power, from their running so near to the centre of motion in the joint; and that, in fact, they require some additional means to aid the extension of the leg.

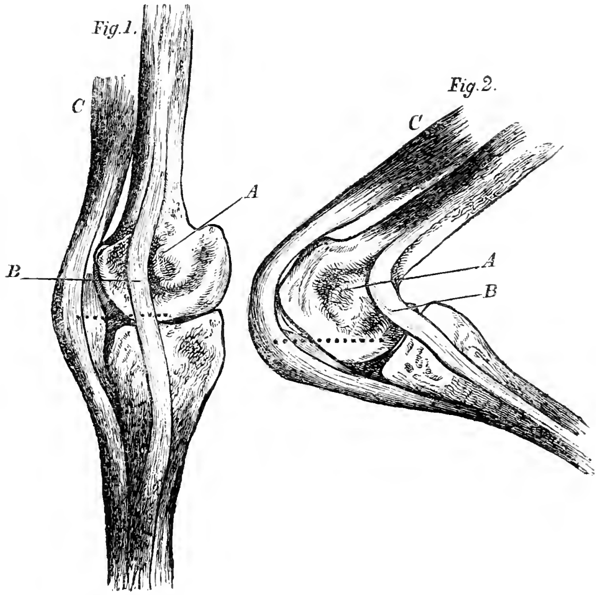


Suppose that the head of the lesser metacarpal bone A enters into the composition of the joint,

it does not appear that by its yielding when the foot is upon the ground, the bones of the carpus can descend, as long as they are sustained by the greater metacarpal or cannon bone. I do not, therefore, conceive that this bone can add to the elasticity of the foot. But when we perceive that the head of the splint bone is behind the centre of motion in the joint, it is obvious that it must be more pressed upon in the bent condition of the joint, when the foot is elevated; and that then the bone must descend. If the splint bone be depressed when the limb is raised and bent, and have a power of recoiling (which it certainly has), it must aid in throwing out the leg into the straight position and assist the extensor muscles of the knee. Further, we can readily believe that when the elasticity of these splint bones is lost, by ossification uniting them firmly to the cannon bone, the want of such a piece of mechanism, essential to the quick extension of the foot, will make the horse apt to come down.

The mechanism of the bones and tendons of the extremities is infinitely varied; and we hardly ever survey anything uncommon in the outward configuration of an animal, but we find also something new and appropriate in the anatomy. The gait, or rather strut, of the ostrich is peculiar, and it results from a very singular

mechanism, a *spring joint*, at the part corresponding with the hock.*



OF THE HORSE'S FOOT.—On looking to the sketch, page 97, and comparing it with that of the hand on page 88, we see that in the horse's

* These figures illustrate the structure referred to. There is a gentle rising of the bone at A. having a smooth lubricated surface, and a groove in front and behind. In the straight position, the ligament B. is lodged in the deep groove at the back of the tubercle; but as the leg is bent, the ligament glides over the tubercle, and becomes lodged in the shallower groove in front. Thus, as the leg is bent and extended, the ligament plays over the two sides of the tubercle, as over a double inclined plane; it is accordingly stretched to the utmost, as it reaches the highest

leg the five bones of the first digital phalanx are consolidated into the large pastern bone; those of the second phalanx into the lesser pastern or coronet; and those of the last phalanx into the coffin bone.

Nothing is better suited to illustrate our subject than the horse's foot: it is a most perfect piece of mechanism. And whilst examining it, we shall be able to infer the peculiarity of living mechanism,—that it can only be preserved perfect by the natural exercise of its parts. The horse, a native of extensive plains and steppes, has a structure admirably suited to these his natural pasture grounds. When brought, however, into subjection, and running on our hard roads, his feet suffer from concussion. The value of the horse, so often impaired by lameness of the foot, has made the structure of this part an object of great interest; and I have it from the excellent professor of veterinary surgery to say that he has never demonstrated the anatomy of the horse's foot, without finding something new to admire.

The weight and power of the animal require

point of the convexity of the tubercle, and it then slips with a sudden jerk into the groove either in front or behind. The object of this peculiar structure seems to be to knit or support the joint, when the weight is directed upon the limb, and to admit of the superior bone being projected backwards to a very unusual degree in the bending of the limb, so as to give additional lever power to the muscle c. which projects the bird in its course.

that he should have both strength and elasticity combined in his foot. Hence the first thing that attracts attention is the position of the bones. Had they been placed the one directly over the other, there could have been no elasticity; accordingly they are placed obliquely over each other; and a strong elastic ligament runs along behind them, terminating by an attachment to the lowest or coffin bone.* So essential is the obliquity of the bones to the elasticity of the limb, that by observing the position of the pastern bones, and coffin bone, it is possible to say whether or not a horse goes easily, without mounting it.

The bones of the foot of the camel rest on a soft elastic cushion. There is a texture of the same kind in the horse's foot, but it acts very differently, and never comes to the ground; nor indeed does the sole of the horse's foot bear its weight. The horny frog, the triangular projection in the hollow of the hoof, has this elastic frog or cushion placed above it; and these together are essential parts, inasmuch as they receive the weight of the animal, and by their

* The convexity of the bones, and the distinctness of the elastic ligament, and of the tendons behind the cannon bone, can be perceived by the eye and by the hand, and constitute one of the "points" of a horse. Such is the correspondence between the strength of an animal's bones, tendons, and muscles, that in those sinews, the jockey can see the perfection or the defect of the whole.

descent press out the crust, or that part of the horny hoof which we see when the foot is on the ground. The anterior tip of this crust, or the part which last touches the ground as the foot rises, is very dense and firm, to withstand the pressure against the ground and the impulse forward: the lateral part of the crust, however, is more elastic, and on its play depends that elasticity of the foot which prevents concussion.

This crust is not consolidated with the bone called coffin bone; certain elastic laminæ are interposed between them. When the animal puts his foot to the ground, the weight bears on the coffin bone; and from this bone being attached to the circle of the crust, by these elastic laminæ, the lateral parts yield, and the weight is directed on the margins of the crust; the sole never touching the ground, unless it has become diseased.

Xenophon, speaking of the Persian horses, says that their grooms were careful to curry them on a pavement of round stones, that by beating their feet against a firm and irregular surface, the texture of the foot might be put into exercise. It corresponds curiously with this, that our high-bred horses are subject to a disease of the foot, from which heavy draught horses, and Flanders horses are exempt. The heavy horse, with less blood than the race horse, lifts its foot in a circle, and comes forcibly on the ground: whilst the

horse for the turf, being light, moves with the foot close to the ground; no time is lost in lifting the foot high in the semicircle; the consequence of which is, that from the foot coming thus down gently, it wants the full play of the apparatus. Hence it may be understood how the lighter horse is subject to contractions of the foot. The bones, ligaments, and crust are out of use; the sole becomes firm as a board, the sides of the crust are permanently contracted, the parts have no longer their elastic play, and the foot striking our hard pavement suffers a shock or concussion; then comes "a fever of the foot," which is inflammation, and that goes on to its total destruction. The proof of all this is, that by paring and softening the exterior of the hoof, so as to restore its elasticity, the veterinary surgeon cures this contracted foot; unless the inflammation has been permitted to destroy the fine apparatus entirely.

That a relation should exist between the internal structure of the foot and its covering, whether it be nail, or crust, or cloven hoof, we can hardly doubt: and an unexpected proof offers itself in the horse. There are some very rare instances of a horse having digital extremities. According to Suetonius, there was such an animal in the stables of Cæsar; another was in the possession of Leo X.; and Geoffroy St. Hilaire says, that in addition to those, he has

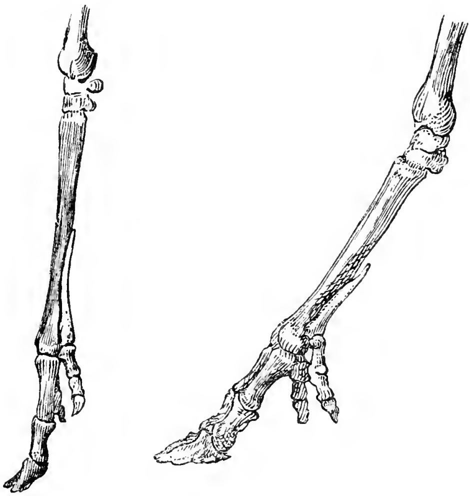
seen a horse with three toes on the fore-foot, and four on the hind foot.* In all these instances of deviation from the natural structure of the bones, there was a corresponding change in the coverings—the toes had nails, not hoofs. By such examples, it is made to appear still more distinctly, that a relation is established between the internal configuration of the toes and their coverings—that when there are five toes complete in their bones, they are provided with perfect nails —when two toes represent the whole, as in the cleft foot of the ruminant, there are appropriate horny coverings—and that when the bones are joined to form the pastern bones and coffin bone, there is a hoof or crust, as in the horse, couagga, zebra, and ass.

In ruminants there is a cannon bone, but the foot is split into two parts, and this must add to its spring or elasticity. I am inclined to think that there is still another intention in this form; it prevents the foot sinking in soft ground, and permits it to be more easily withdrawn. We may observe how much more easily the cow withdraws her foot from the yielding margin of a river, than the horse. The round and concave form of the horse's foot is attended with a vacuum or suction as it is withdrawn; while the

* Such a horse was not long since exhibited in Town, and at Newmarket.

split and conical shaped hoof expands in sinking, and is easily extricated.

In the chamois and other species of the deer



there is an additional toe.* A sort of lesser cannon bone, with its two pasterns, supports this toe, and is joined by ligament to the larger cannon bone, so that it must have great elasticity. As a division of the flexor tendon runs into it, it must increase the spring when the animal rises from its crouching position. We see, in these sketches, that the lesser metacarpal bone, which, in the horse, entered into the joint of the "knee," as the splint-bone, is here brought

* The left hand figure represents the bones of the foot of the antelope; the right, those of the rein-deer.

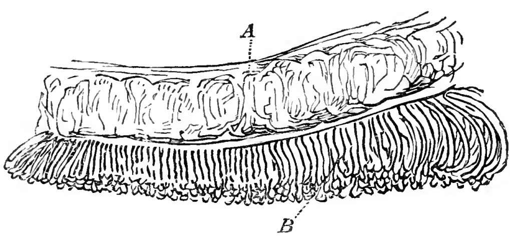
down to increase the elasticity, or power of expansion of the foot.

The two lateral toes of the hog are short, and do not touch the ground, yet they must serve to sustain the animal when the foot sinks. In the rein-deer these bones are strong and deep, and the toe, by projecting backwards, extends the foot horizontally—thus giving the animal a broader base on which to stand, and adapting it to the snows of Lapland, on the principle of the snow-shoe. The systematic naturalist will call these changes in the size, number, and place of the metacarpal and phalangeal bones "gradations;" I see in them only new proofs of the same system of bones being applicable to every circumstance, or condition of animals, and furnishing us with other instances of *adaptation*.

I have explained why I think that the bones of the elephant's leg stand so perpendicularly over each other; there is a peculiarity also in the bones of the foot. In the foot of the living animal we see only a round pliant mass, which, when he stands, resembles the base of a pillar, or the lower part of the trunk of a stately tree. But when we examine the bones of the foot, we find this broad base to consist of the carpus, metacarpus, and phalanges of the toes; and these bones have a very different use from what we have hitherto noticed. They are not connected with a moveable radius, and have no

individual motion, as in the carnivorous animal —they merely serve to expand the foot, the base of the column, and to give it a certain elasticity.

In the sketch (page 65) I have placed the bones of the foot of the camel in contrast with those of the elephant. The camel's foot having no such disproportioned weight to bear as that of the elephant, lightness of motion is secured by the oblique position of its bones, as well as by the direction of the bones of the shoulder, which we have formerly noticed. In the soft texture of the camel's foot there is much to admire; for although the bottom be flat, like the sole of a shoe, yet, as we have said, there is between the bones and tendons, and the horny sole, a cushion so soft and elastic that the animal treads with great lightness and security. The resemblance of the foot of the ostrich to that of the camel has not escaped naturalists; * there



is the same softness and pliancy of the foot, and it is provided for by similar means—another

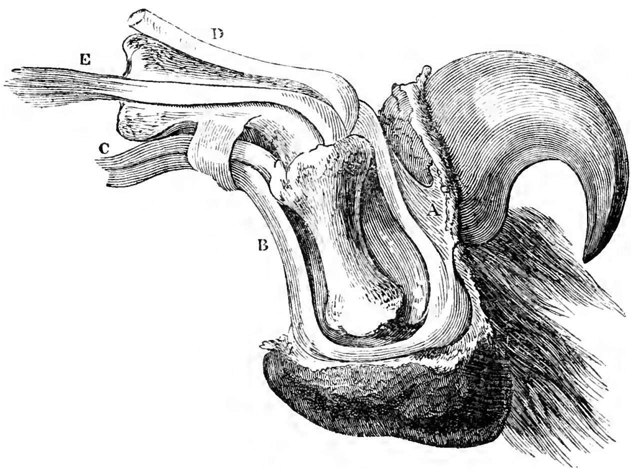
* A. the frog or elastic pad in the ostrich's foot. B. processes from the horn or cuticle, disposed like the hair of a brush, and forming the sole.

adaptation of the *frog* or elastic pad. We have our pads also; the best, though not the only example of which is in the heel. The texture under the bone of the heel is neither ligamentous, nor cartilaginous, nor fatty, but a happy union of all; in which elastic fibres are so interwoven with the softer matter, that it expands and rises on pressure.

We are now treating of the last bones of the fingers; and let us once more see how much may be accomplished, by the study of one of these bones, in bodying forth the whole animal. I allude to the dissertations of the President Jefferson and Baron Cuvier on the Megalonix. We must preface this part of our subject by some remarks on the form of the claws of the lion.

The canine tribe are carnivorous, like the feline; and both have the last bones of their toes armed with nails or claws. But their habits and means of obtaining food are different. The first combine a keen sense of smelling with a power of continued speed; they run down their prey. The feline order owe their superiority to the fineness of their sight, accompanied with a patience, watchfulness, and stealthy movement; they spring upon their prey, and never long pursue it. They attain their object in a few bounds, and, failing, sulkily resume their watch. When we look to the claws, we see a correspon-

dence with those habits. The claws of the dog and wolf are coarse and strong, and bear the pressure and friction incident to a long chase; they are calculated to sustain and protect the foot. But the tiger leaps on his prey, and fastens his sharp and crooked claws in the flesh. Now we must admire the mechanism by which they are preserved thus curved and sharp at their points. The last bone, that which supports the claw, is placed laterally to the penultimate bone, and is so articulated with it, that an elastic ligament (A) draws it back and to one side, and



thus raises the sharp extremity of the claw upwards, and preserves it in that position. The nearer extremity of the furthest bone thus presses the ground, in the ordinary running of the ani-

mal,* whilst the claw is retracted, as into a sheath, between the toes. But when the tiger makes his spring and strikes, the claws are uncased by the action of the flexor tendons; and they are so sharp and strong in the Bengal tiger, and his arm is so powerful, that they have been known to fracture a man's skull by a touch, in the act of leaping over him.

To return to the observations of President Jefferson on the Megalonix. Having found a bone, which, by its articulating surface and general form, he recognised to be one of the

* The pads in the bottom of the lion's foot protect these bones; they are soft cushions, which add to the elasticity of the foot, and must, in some degree, defend the animal in alighting from his bound. I could not comprehend how the powerful flexor muscles did not unsheath the claws, whenever the lion made his spring, and how they only produced this effect, when he was excited to seize and hold the prey. I made this dissection to detect the cause. The last bone of the toe, from being drawn back by the elastic ligament (A) beyond the centre of motion of the joint, is placed in such a peculiar relation to the penultimate bone, that when the animal uses his foot in mere progression, the flexor tendon (B), although inserted into the last bone, only acts in forcing its nearer end, and the cushion of the toe, to the ground. But when the lion strikes his prey to seize it, a more general excitement takes place in the muscles called interossei and extensors, (D, E); the relative position of the two last bones is altered; the nearer end of the last bone is withdrawn from beyond the centre of motion of the joint, so that the action of the flexor tendon can now draw it forward or in a line with the penultimate bone,—thus unsheathing and uncovering the claw, and preparing it to hold or to tear.

bones of the phalanx of an animal of great size, he thought he could discover that it had carried a claw. From this circumstance, he naturally enough concluded (according to the adage—ex ungue leonem) that it must have belonged to a carnivorous animal. He next set about calcu-

lating the length of this claw, and estimating the size of the animal: and he satisfied himself that in this bone, a relick of the ancient world, he had obtained a proof of the existence during these old times, of a lion, of the height of the largest ox, and an opponent fit to cope with the mastodon. But when this bone came under the scrutiny of Baron Cuvier, his perfect knowledge of anatomy enabled him to draw a different conclusion.

He first observed that there was a spine in the middle of the articulating surface of the last bone; which in this respect was unlike the form of the same bone in the feline tribe. He found no provision in this specimen for the lateral attachment of the bone; which we have just shown to be necessary for its retraction. Then

observing the segment of the circle that this bone formed, he prolonged the line in the corresponding circumference, and showed that the claw attached to it must have been of such great length, that it could never have been retracted to the effect of guarding its acute and curved point. The point, therefore, could not have been raised vertically, as in the lion, so as to have permitted the animal to put the foot to the ground without blunting the instrument! Pursuing the comparison, he rejected the idea of the bone belonging to an animal of the feline tribe at all. His attention was directed to another order of animals, the paresseux or sloths, which are characterized by having long nails affixed to their toes. But their nails are folded up in a different fashion from the claws of the feline tribe; they just enable the animal to walk; but slowly and awkwardly, somewhat in the same manner is if we were to fold our fingers on the palm of the hand, and bear upon our knuckles (p. 32). On instituting a more just comparison therefore between these bones of the ancient animal and the corresponding bones of the paresseux, Cuvier has satisfied us that the supposed lion of the American President was an animal which scratched the ground and fed on roots.

One experiences something like relief to find that there never was such an enormous carnivorous animal as this denominated megalonix.

These unguical bones, or bones of the claws, exhibit a very remarkable correspondence with the habits and general forms of animals. Besides what we have seen in the lion, or tiger, in the dog or wolf, in the bear, and ant-eater, there is a variety, where we should least expect it, in the animals that live in woods, and climb the branches of trees. The squirrel, having his claws set both ways, runs with equal facility up and down the bole, and nestles in the angles of the branches. The monkey leaps, and swings himself from branch to branch, and in springing, parts from his hold by the hinder extremities, before he reaches another branch with the anterior extremities; he leaps the intervening space, and catches with singular precision. But the sloths do not grasp; their fingers are like hooks, and their strength is in their arms. They do not hold, but hang suspended to the branch. They never let go with one set of hooks, until they have caught with the other; and thus they move along the branch, using both hind and fore feet, whilst their bodies are pendant. Here we see, once more, how the form of their extremities, the concentration of their strength, and their habits, correspond in these animals, not merely with their haunts in the forest, but with their mode of moving and living among the branches; all active, but in a different manner.

There have been of late deposited in our

Museum in the College of Surgeons, the bones of an animal of great size ;* and the examination of them affords an opportunity of applying the principles and the mode of investigation followed by our great authority in this part of science. These remains consist of part of the head, spine, tail, pelvis, and the bones of one hinder extremity, and the scapula. Estimating the height of the animal to which they belonged at seven feet, it scarcely conveys an adequate idea of its size; for the thigh-bone is three times the diameter of that of the large elephant, which is in the same collection, and the pelvis or haunch-bone, twice the breadth of that of the elephant. If we form our opinion of its configuration, on those principles to which we have had repeated occasion to refer and judge of its strength, by the size and prominence of the processes of these bones, we must conclude that the animal possessed great muscular power; and directed by the same circumstances still, we may obtain an idea of the manner in which that muscular power was employed.

On comparing the bones with the drawings of the skeleton of the enormous animal preserved in the Royal Museum of Madrid, it is seen, at once, that this new acquisition is part of the remains of the great fossil animal of Paraguay, the Megatherium of Cuvier. And every observation

* When this was written the author was one of the Council of the Royal College of Surgeons of London.

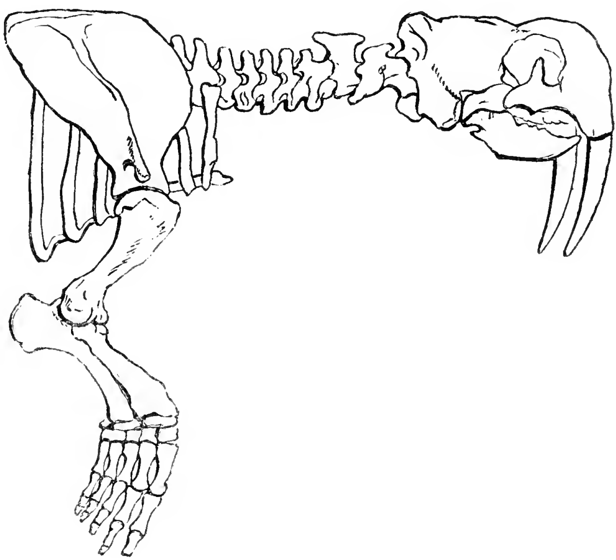
which we are enabled to make on the extreme bones of the foot, on the scapula, and on the teeth, confirms the idea entertained by Cuvier, that it was a vegetable feeder; that its great strength was employed in flinging up the soil, and digging for roots. Its immense muscular power seems to have been concentrated in its paws, corresponding with the provisions in the bones of its feet for enormous nails or claws. I have heard it surmised that this animal may have sat upon its hinder extremities, and pulled down the branches of trees to feed upon them. It is only its great size there that can countenance such an idea. We have not the humerus, which, by its processes, would have declared the classification and activity of the muscles of the anterior extremity, but by the pelvis and enormous bones of the posterior extremity, we can estimate the height, breadth, and strength of the animal; while by the scapula and clavicle we can form some conception of the extent of motion of the anterior extremity, and the great power that it possessed. In short, judging from the bones that have been preserved, we perceive that the strength of the Megatherium was not so much in the body, (certainly not in the jaws,) as in the extremities, and especially in the posterior extremities: and that its strength was given neither for rapidity of motion nor for offence, but for digging.

How little was it to be expected that an alliance between anatomy, the most despised

part of it, and mineralogy, was to give rise to a new science;—making a department of natural history which had been pursued in mere idleness, vaguely, and somewhat fancifully, to be henceforth studied philosophically, and by inductive reasoning. It is both interesting and instructive to find the relations thus established, between departments of knowledge apparently so remotely connected.

In the true Amphibia, as the phoca and walrus, the feet are contracted, and almost enveloped in the skin, and the toes webbed and converted into fins.

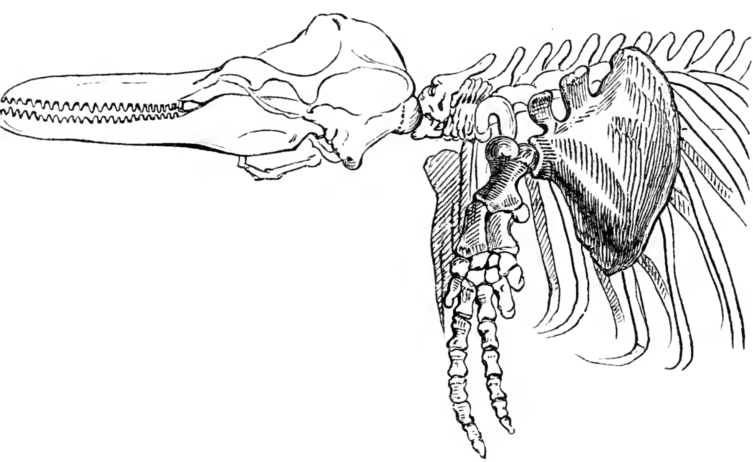
We have sketched here the bones of the morse, or walrus; and they are remarkably com-



plete, if we consider the peculiar appearance of the feet in the living animal. The bones are accommodated to form an instrument for swimming; for these animals live in the water: they come to land only to suckle their young, or to bask in the sun; and out of the water they are the most unwieldy and helpless of all animals which breathe.

In the Cetacea, for example, the whales, we see mammalia unprovided with hind feet. The scapula is large, the humerus very short, and the bones of the fore-arm and hand flattened and confined in membranes which convert them into a fin. These animals live in the water, but they must rise to the surface to breathe.

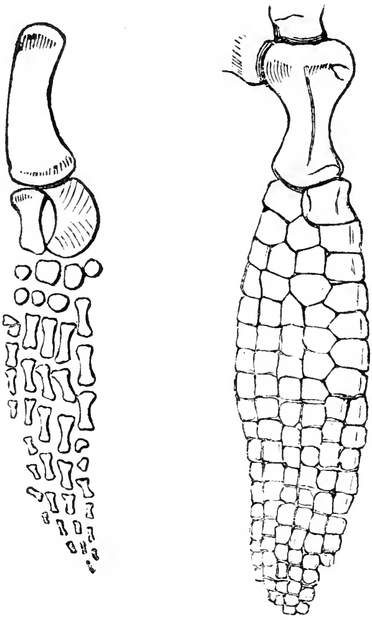
I need not say that in the dolphin we recog-



nise the bones of the anterior extremity, only a

little further removed from the forms which we have hitherto been contemplating. The seal and morse raise themselves out of the water, and lie on the rocks; but the different species of the dolphin continue always in the water; the extremity is now a fin or an oar, and those who have seen the porpoise or the pelloch in a stormy sea, must acknowledge how complete the apparatus is, through which they enjoy their element.

The last examples I select, shall be from the ancient world.*

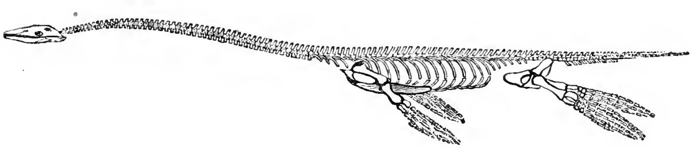


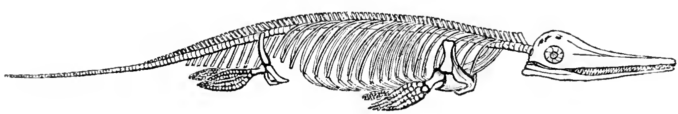
* The figure to the left is the anterior extremity of the Plesiosaurus; to the right, that of the Ichthyosaurus. In these paddles

These figures are taken from specimens in the College of Surgeons, of fossil animals of singular structure, between the crocodile and the fish, the ichthyosaurus and plesiosaurus. They are imbedded in a calcareous rock, and the skeletons are entire, but crushed, and a good deal disfigured. Here are only the extremities or paddles; consisting of a multitude of bones articulated together: but among these we still recognize the humerus, radius and ulna, and bones of the carpus and fingers. No fault is to be found with the construction of these instruments; they are suited to their offices, and no bone is superfluous, or misplaced, or imperfect; for the ichthyosaurus and plesiosaurus inhabited the sea. Their remains are found low in the lias deposit. Great changes have been wrought on the land and on the deep, since they existed; and the race of animals, the structure of whose extremi-

we see the intermediate changes from the foot of animals to the fin of the fish—modifications of the fins of the walrus, dolphin, or turtle. In the plesiosaurus, and ichthyosaurus, we no longer find the phalanges, or attempt to count the bones; they become irregular polygons or trapezoids—less like phalanges than the radii of the fins of a fish. In fishes the anterior extremity is recognised in the thoracic fin; and we may even discover the prototypes of the scapula and the bones of the arm connected with it. I know not what the naturalist, who likes to note the gradual decrease of the elementary parts, makes of these hundred bones of the paddle or of the fin; where there is an increase of the number, whilst, relatively speaking, there is a defect in the form and motion, of the parts.

ties we have hitherto been engaged in examining, was not then in being. When we discover, therefore in the animals of the old world that their skeletons were formed of the same series of bones that compose the skeletons of animals now alive, we must admit the existence of the same system, and acknowledge the progressive developement of that system, through a period of time incalculably remote; even if, instead of our days and years, referable to history, each day were as a thousand years; or if we were to make our estimate, by the records of the revolutions which have left their traces on the globe itself.*



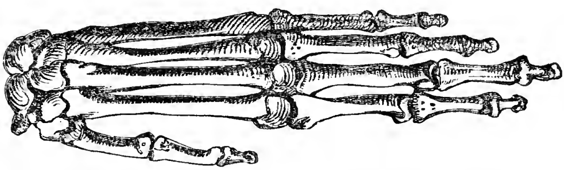


I have now given, I hope, sufficient examples of those changes in the bones of the anterior extremity, which suit them to every possible variety of use. After a little attention to the

* The wood-cuts on this page give some idea of the forms of the skeletons of the ichthyosaurus and plesiosaurus restored by the Rev. Mr. Conybeare.

form of the bones of the human hand, I shall take up another division of my subject.

In this sketch we have the bones of the paw of the adult Chimpanzee, from Borneo; and the



remarkable peculiarity that distinguishes it from the human hand, is the smallness of the thumb; it extends no further than to the root of the fingers. Now, it is upon the length, strength, free lateral motion, and perfect mobility of the thumb, that the power of the human hand depends. The thumb is called *pollex*, because of its strength; and that strength is necessary to the power of the hand, being equal to that of all the fingers. Without the fleshy ball of the thumb, the power of the fingers would avail nothing; and accordingly the large ball, formed by the muscles of the thumb, is the distinguishing character of the human hand, and especially of that of an expert workman.*

The loss of the thumb almost amounts to the

* Albinus characterises the thumb as the lesser hand, the assistant of the greater—*manus parva, majori adjutrix.*

loss of the hand, and were it to happen in both hands, it would reduce a man to a miserable dependence: or as Adoni-bezek said of the threescore and ten kings, the thumbs of whose hands and of whose feet he had cut off, "they "gather their meat under my table."

In a French book, intended to teach young people philosophy, the pupil asks why the fingers are not of equal length? The form of the argument reminds us of the difficulty of putting natural questions—the fault of books of dialogue. However, the master makes the scholar grasp a ball of ivory, to shew him that the points of the fingers are then equal. It would have been better had he closed the fingers upon the palm, and then have asked whether or not they corresponded. This difference in the length of the fingers serves a thousand purposes, adapting the form of the hand and fingers, as for holding a rod, a switch, a sword, a hammer, a pen, or pencil, engraving tool, &c., in all which, a secure hold and freedom of motion are admirably combined. But we must defer this part of our subject until we have shewn the application of the muscles to the bones, and the appropriate structure of the ends of the fingers to bestow feeling.

In conclusion,—what says Ray,—"Some "animals have horns, some have hoofs, some "teeth, some talons, some claws, some spurs

" and beaks: man hath none of all these, but is " weak and feeble, and sent unarmed into the " world—Why, a hand, with reason to use it, " supplies the use of all these."

In taking leave of this part of our subject, let us mark the importance of these comparative views of anatomy, to the science of Geology. It has been ingeniously and quaintly said that the organized remains imbedded in the rocks, are as the medals struck in commemoration of the great revolutions which the earth has undergone.

Every one must have seen that the crust of the earth is formed in strata or layers: and a very slight consideration leads also to the belief that this surface has been subject to great convulsions, as well as having successive deposits or formations laid upon it. Each of these layers is to a certain degree distinct in the chemical composition, or in the fracture and external character, of its minerals, but chiefly in the nature of the animal remains which are buried in it.

Of these strata, some are distinguished by containing the bones of large animals. Now, it is by attending to the forms and processes of these bones, that by far the most interesting conclusions, in the whole range of this new science, may be drawn. A very short account of the successive deposits, forming the different strata,

will serve to illustrate the importance of the anatomy of the animals which have the true bony skeleton, to the geologist.

The last grand revolutions have formed a surface to the earth, in which strata, of every condition, have been exposed. And indeed, we might say that such exposure, by laying open the riches of the earth as well as furnishing the mixed soil for vegetation, has been the end of these convulsions. At all events, the variety of objects disclosed on the surface tends to confound the enquirer: and, therefore, we must shortly recapitulate what has been discovered by the investigations of scientific and ingenious men in our time.

Without hazarding conjectures on the elevation or production of the "primitive rocks," we have at present only to notice the stratifications superimposed. Of these, the most striking and the most difficult to reconcile to theory, are the strata of coal: but we pass over them as containing no animal remains in which the knowledge of the anatomy of the vertebrata can be of use. On the supposition that these beds of coal are vegetable productions, we might expect to find the remains of terrestrial animals within them: but it is conjectured that the vegetables which compose them, were not such as we are now familiar with, and that the land where they grew did not form a suitable habitation for ani-

mals corresponding with those of the present epoch.

Above the beds of coal, are strata, regular, well ascertained, and interesting as indicating the presence of the coal beneath. The next remarkable stratifications above them come to be connected with our subject; because they contain the remains of gigantic animals, with a regular skeleton, on the system of the vertebrata.

Some of the oviparous quadrupeds, here alluded to, are estimated to have been eighty feet in length.* But although their skeletons were formed on the plan, if we may thus express it, of quadrupeds, the extremities of many of them were more like paddles than feet:† and we conclude that they were capable of dragging their huge bulk on the land, because the structure of their skeletons proves that they were oviparous and breathed the atmosphere. Some of them had a conformation in their extremities, resem-

* The Megalosaurus, discovered by Professor Buckland in Oxfordshire, is supposed to have been about seventy feet in length. The Iguanadon, an herbivorous masticating reptile, first discovered by Mr. Mantell in the Wealden beds, in Sussex, is computed to have been seventy or eighty feet in its entire length, its tail being fifty feet, its height nine feet, its hind foot six feet and a half, and its body about the same thickness as the elephant's. The Hylæosaurus, the last discovered of these huge animals in the same beds, and supposed by Mr. Mantell to have been a reptile intermediate between the crocodiles and the lizards, is estimated to have been about thirty feet in length.

† See page 120, and also the Appendix.

bling that of the recent oviparous quadrupeds, for enabling them to walk or crawl on slimy ground; and judging by the habits of these, as of the crocodile, gavial, alligator, and cayman, certain species of which existed among them, it is probable that they lived in still water, with muddy bottom, retreating under the mud, and projecting their snouts between the aquatic plants, to breathe. And they must have been prolific to an extraordinary degree, as they had not for enemies, the vulture and the ichneumon, which destroy multitudes of the eggs of these creatures of the present day. Others seem to have had their skins extended on their anterior extremities,* if not to provide a power of flight, at least to allow them to drop in safety from the elevations to which they might have crept.

The stratified rocks which contain these oviparous reptiles are composed of lime, clay, or sandstone, and are known under the denominations of lias, oolite, Wealden or Sussex beds, Stones-field slate, &c. They are visible in the south of England, and extend to many parts of Europe. There is every appearance of these deposits having been submerged and deeply buried in the ocean: from which thick beds of chalk have been deposited over them. Above the chalk, again, is to be found a series of stratified rocks, implying a new condition.

* The Pterodactyles, see page 87.

The lowest layer of this "tertiary formation" situated above the chalk, is sometimes called the product of the Palœotherian period. In this deposit, animals of a distinct creation, the species of which cannot be identified with those imbedded in the strata under the chalk, are found. Then for the first time, was there a condition of the earth suited for terrestrial animals, which retire under the shade of woods and give suck, the mammalia. Yet it is remarkable, that in this lowest stratification of the tertiary formation, the animals of the class mammalia only approached in resemblance to those which are now alive: we find the remains of such only as are now extinct.

When the layers forming the tertiary beds are examined in succession upwards, they are still distinguishable by their organic products: and as we approach the surface, if theory has not quite deceived us, there are fewer remains of the extinct quadrupeds, and more numerous specimens of such as now inhabit the earth. We find, in the different strata, the bones of the mammoth, the megatherium, the elephant, the tapir, the rhinoceros, the hippopotamus, the stag, the ox, the horse, and with them the skeletons of their natural enemies of the feline tribe, and the bear and the hyæna, the bones of which prove them to have been of greater strength and size than those that are now alive.

Over the earth's surface, as thus formed, there are evidences that a deluge has swept, with inconceivable power, brushing off the superficial strata, rolling immense rocks, and depositing the debris, so as to fill chasms, form new accumulations, and once more to change the whole character of the earth's surface.* It was then that the surface of the globe assumed its present confines of land and sea, and that the valleys and the courses of rivers were determined. Out of these convulsions and successive revolutions has come that condition of the world which we now enjoy, and, as I shall have occasion to repeat, no previous state of the earth's surface would have been suitable to our constitution.

* When doctrines or principles are laid down dogmatically, there is an end of reasoning; "they are as fetters on the feet, and like manacles on the right hand." In this way, the most famous schools have sunk; for if it become a crime to doubt or investigate, the mind decays. When God informed us of our duties to Himself and to each other, the exercise of our affections was enjoined and left free. To have taught mankind the nature of physical things, would have made it the duty of the pious to seek no further knowledge, and researches into them would have implied presumption. But by the constitution of the mind, we learn that had we been left in a state of passive obedience, without object or impulse, the loss of the affections as well as of reason would have followed; our sense of goodness and of benevolence would have become obtuse, and the charities of life and the love and duty we owe to God must have decayed in us.

Why then do geologists quote scripture, and form their opinions of the structure of the earth on the Mosaic account of the creation? It does not require deep theological knowledge to

The waters as they flow to the ocean, and as they are there met by tides and currents, accumulate mud, gravel, and the remains of animals of the species which now exist. The deposits which have thus taken place are distinguished from those produced by the grand revolutions which preceded, by the term 'alluvium.'

My admiration of the labours of our geologists partakes of a feeling of gratitude. But yet there is something in the subject which leads the devoted student to be too ambitious, and to frame theories almost too comprehensive. It is not enough for the geologist to say that, after all, the changes on the earth's surface which he describes as having taken place, are not greater, in comparison with the size of the earth, than

comprehend what was intended by that sublime announcement. It was addressed to a people ever prone to fall into the idolatries of surrounding nations. In teaching the Creation of the world, it affirmed the existence of One God pre-existing and eternal. It denied the existence of gods and demons sprung from the earth: it denied that the deluge was one of a necessary succession of events: or that the earth was subject to be successively destroyed and restored: or that those who flourished to the advantage of mankind in one period, should be restored to a similar existence in another. It taught the just relations of the heavenly bodies to the earth, and that they were not the abodes of deified mortals—for these were opinions maintained by the surrounding nations. Surely, then, men are inconsistent, when digging the earth for fossils, they at the same time expect to find in the scriptures (which teach the unalterable religious and moral duties) the principles of an uncertain science.

the cracks in the varnish are to the globe that stands on the table. It has been part of our object to show that the features of our globe, and the phenomena around us, are suited, and intended, to excite the faculties and imagination. Accordingly, when the mineralogist extends his survey from the mountains, over extensive plains, and looks down into the ravines and valleys, and persuades himself that he can say when and how they have been formed, he is tempted to indulge in an enthusiasm which can only be permitted in the poet. Wonderful improvements have, indeed, been made in this science by our countrymen who have associated themselves for this purpose. Buckland, Conybeare, and Mantell, are especially distinguished for the discovery of these large Saurian reptiles; whilst other geologists have exerted their genius and industry with equal effect in different departments. But it is in contemplating the labours of Cuvier, that we have the earliest and the best proofs of the importance of comparative anatomy, in giving extraordinary interest to this science. In him there was combined an attention to minute things, with a power of generalizing, highly characteristic of genius. Years had been passed in accumulating the animal remains from the quarries round Paris; and out of this heap, which lay as confused as if the bones had been washed to his feet by a torrent, he was enabled, by fol-

lowing the principle which the early part of this chapter has shown to prevail—the co-existence of the parts of the skeleton—to put together the separate members, to build up the skeletons of extinct animals anew, and to present them to us with a precision which we could only have expected from the dissection of the recent animals.

As comparative anatomy has given the principal interest to geology, so human anatomy and the knowledge of the human endowments and faculties, have prevented the doctrines of the naturalist and geologist from falling into materialism.

The phenomena visible in the heavens, on the earth, and within it, are of a nature, taken by themselves, to overwhelm the enquirer's mind. He must consider himself, his physical endowments and capacities; he must compare these endowments with the elements around him and consider their just relations, to learn his own value. When he has acquired this conviction, he may trace the field back with the naturalist and learn the correspondence between things vital and physical of the old world. But without a true conception of the position and relations of man, the whole range of natural science is barren of consolation.—The periods of the revolutions are too vast—the objects too distant—to seem to have as their prospective design, the condition of the human race.

"God made the country;" and it is perhaps in surveying plains and meads and mountains remote from man that the mind is most elevated to pure and high contemplations. But towns, temples, and the memorials of past ages, bridges, aqueducts, statues, pictures, and all the elegancies and comforts of the town, are equally the work of God, through the propensities of His creatures, and we must presume, for the fulfilment of design. The condition of the earth has by successive revolutions been made to conform to these works of man and afford the means for them. The metallic veins of the primitive rocks have been exposed. The carboniferous strata, the lime and free stone, have been disjointed and elevated: the riches of the interior of the earth as well as of its prolific surface, the circulation of water and the formation of springs —all give proof that it was designed that the earth should be subdued to man's use, that he should not live a selfish solitary nomade life, but in society, where his higher faculties should be called into activity and his social virtues exercised.

CHAPTER IV.

Of the Muscles of the Arm and Hand—their Vital Action—their Mechanical Adaptation to the Motions of the Hand and Fingers—Form of the Human Hand.

The muscle of the body is that fleshy part, with which every one is familiar. It consists of fibres which lie parallel to each other. This fibrous, or filamentous part, has a living endowment, a power of contraction and relaxation, termed irritability. A single muscle is formed of some millions of these fibres combined together, having the same point of attachment or origin, and concentrating in a rope or tendon, which is fixed to a moveable part, called its insertion. We may demonstrate upwards of fifty muscles of the arm and hand, all of which must consent to the simplest action; but this gives an imperfect view of the extent of the relation of parts which is necessary to every act of volition. We are most sensible of this combination in the muscles, when inflammation has seized any of the great joints of the body: for even when in bed, every motion of an extremity then gives pain, through the ne-

cessity of a corresponding movement in the trunk. When we stand, we cannot raise or extend the arm without a new position of the body, and a poising of it, through the action of a hundred muscles.

ON THE ACTION OF THE MUSCLES OF THE ARM.

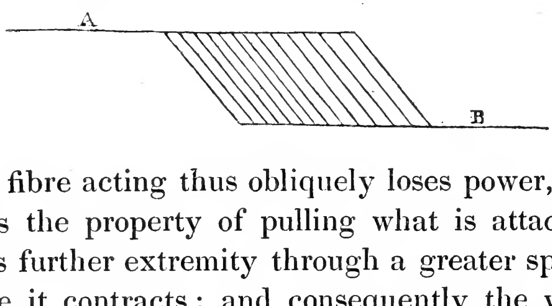
We shall consider this subject under two heads; in the first, we shall give examples of the living property of the muscles; and then of the mechanical contrivances, in their form and application. In all that regards the muscles, we see the most bountiful supply of power commensurate to the object, but never any thing in the least degree superabundant. If the limb is to be moved by bringing a muscle, or a set of muscles into action, the power is not given in that excess which would enable them to overcome their opponents; but the property of action is withdrawn from the opponents; they become relaxed, and the muscles, which are in a state of contraction, perform their office with comparative ease. A stationary condition of the limb results from a balanced but regulated action of all the muscles; which condition may be called their tone. If, in an experiment, a weight be attached to the tendon of an extensor muscle, it will draw out that muscle to a certain degree, until its tone or permanent state resists the weight: but if the flexor muscle be now excited, this being the

natural opponent of the extensor the weight will fall, by the relaxation of the extensor. So that the motion of a limb implies an active state or a change in both classes of muscles, the one to contract, the other to relax; and the will influences both classes. Were it not so regulated, instead of the natural, easy, and elegant motions of the frame, the attempt at action would exhibit the body convulsed, or, as the physicians term it, in clonic spasms. The similitude of the two sawyers, mentioned by Paley, gives but an imperfect idea of the adjustment of the two classes of muscles. When two men are sawing a log of wood, they pull alternately, and when the one is pulling, the other resigns all exertion. But this is not the condition of the muscles—the relaxing muscle does not give up all effort, so as to be like a loose rope, but is controlled in its yielding, with as fine a sense or adjustment, as is the action of the contracting muscles. Nothing appears to us more simple than raising the arm, or pointing with the finger; yet in that single act, not only are innumerable muscles put into activity, and as many thrown out of action, but both the relaxing and the contracting muscles are controlled or adjusted with the utmost precision, though in opposite states, and under one act of volition.

By such considerations, we are prepared to admire the faculty which shall combine a hundred muscles so as to produce a change of pos-

ture or action of the body; we now perceive that the power taken from one class of our muscles, may be considered as if it were bestowed on the other; so that the property of life, which we call the irritability, or action of a muscle, is upon the whole, less exhausted than would be the case on any other supposition.

As to the second head, our demonstration is of an easier kind. We have said that nature bestows abundantly, but not superfluously; a truth evinced in the arrangement of the muscles. All the muscles of the limbs have their fibres running in an oblique direction,—thus A. being the tendinous origin of a muscle, and B. the tendinous insertion, the fleshy fibres run obliquely between these two tendons.



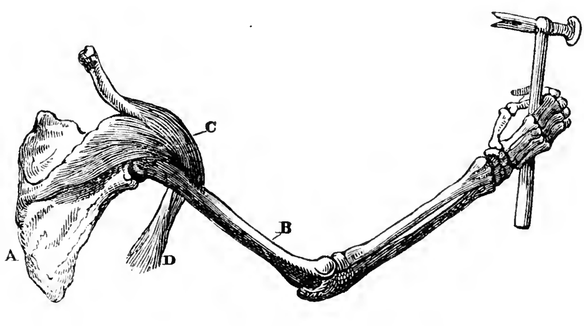
The fibre acting thus obliquely loses power, but gains the property of pulling what is attached to its further extremity through a greater space, while it contracts; and consequently the velocity is increased. This mechanical arrangement is intelligible on the law, that velocity of motion through space, is equal to power or weight. Here in the muscle, there is a resignation of power to obtain velocity of motion. The same effect is produced by the manner in which the tendons of the muscles run over the

joints. They would act more powerfully, if they went in a straight line to the toes or tips of the fingers : but by being laced down in sheaths, they move the toes and fingers with a velocity proportioned to their loss of power.

Let us see how far this corresponds with other mechanical contrivances. A certain power of wind or water being obtained, the machinery is moved; but it is desired to give a blow, with a velocity far greater than the motion of the water or the turning of the wheels. For this purpose a fly-wheel is put on, the spokes of which may be considered as long levers. The wheel moves very slowly, at first; but being once in motion, each impulse accelerates it with more and more facility; at length, it acquires a rapidity, and a centrifugal force which nothing can equal in its effects, but the explosion of gunpowder. The mechanist not having calculated the power of accelerated motion in a heavy wheel, has seen his machinery split and burst up, and the walls of the house blown out as by the bursting of a bomb-shell. A body at rest receives an impulse from another, which puts it into motion—it receives a second blow; now this second blow has much greater effect than the first—for the power of the first was exhausted in changing the body from a state of rest to that of motion—but being in motion when it receives the second blow, the whole power is bestowed on the acceleration of its motion; and so on, by the third and

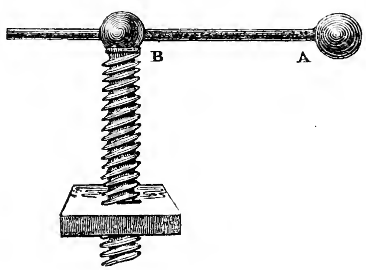
fourth blows, until the body moves with a velocity, equal to that of the body from which the impulse is originally given. The slight blow given to a boy's hoop is sufficient to keep it running; and just so the fly-wheel of a machine is kept in rapid action by a succession of impulses, each of which would hardly put it in motion. If we attempt to stop the wheel, it will give a blow in which a hundred lesser impulses are combined and multiplied.

There is, in the machinery of the animal body, in a lesser degree, the same interchange of velocity and force. When a man strikes with a hammer, the muscle near the shoulder,* C., acts upon the humerus, B., in raising the extended lever of the arm and hammer, with every possible disadvantage, seeing that it is inserted



* A. The scapula, or shoulder-blade; B. the humerus, or arm bone; C. the deltoid muscle of the shoulder, arising from the shoulder-blade and clavicle, and inserted into the arm-bone; D. a muscle which draws the arm down, as in striking with a sword or hammer.

or attached so near the centre of motion in the shoulder joint. But the loss of power is restored in another form. What the muscle D. loses by the mode of its insertion, is made up in the velocity communicated to the hammer; for in descending through a large space, it accumulates velocity, and velocity is equal to force. The advantage of the rapid descent of a heavy body is, that a smart blow is given, and an effect produced which the combined power of all the muscles, without this mechanical distribution of force, could not accomplish. This is, in truth, similar to the operation of the fly-wheel, by which the gradual motion of an engine is accumulated in a point of time, and a blow is struck capable of crushing or of stamping a piece of gold or silver. In what respect does the mechanism of the arm differ from the engine with which the printer throws off his sheet?



Here is a lever with a heavy ball at the end; in proportion to its weight it is difficult to be put in motion. The printer, therefore, takes hold of the lever near the ball, at A. Were he to con-

tinue pulling at that part of the lever, he would give to the ball no more velocity than that of his hand; but having put the ball into motion, he slips his hand down the lever to B. He could not have moved the weight, had he applied his hand here at first; but it being now in motion, the whole strength of his arm is given to the lever at B., whilst the velocity of the great weight at the further end is accelerated. Thus the weight and the velocity being combined, the impulse given to the screw is much greater than if he had continued to pull upon the further end of the lever at A.

If we now turn our eye to the diagram (page 138), we shall understand that the muscle c. raises the long lever of the arm at a disadvantage, or very slowly; but the arm being moved, that motion is rapidly increased by each successive impulse from the muscle; and, of course, the velocity at the further extremity is more rapid than at the insertion of the tendon.

Again, if we consider the action of the muscle D. in pulling down the arm, as in giving a back stroke with the sword, we have the combination of two powers,—weight and muscular effort. When the hammer descends, the rapidity is increased by the mere effect of gravity; but when the action of the muscle is conjoined, the two forces, progressively increasing, greatly augment the velocity of the descent.

The same interchange of power for velocity, which takes place in the arm, adapts a man's hand and fingers to a thousand arts, requiring quick or lively motions. The fingers of a lady playing on the pianoforte, or of the compositor with his types, are instances of the advantage gained by this sacrifice of force for velocity of movement. The spring of the foot and toe is bestowed in the same manner, and gives elasticity and rapidity in running, dancing, and leaping.

The motions of the fingers do not result merely from the action of the large muscles which lie on the fore-arm: these are for the more powerful efforts; but in the palm of the hand, and between the metacarpal bones, there are small muscles, (*lumbricales* and *interossei*) which perform the finer motions, — expanding the fingers, and moving them in every direction with quickness and delicacy. These small muscles, attached to the near extremities of the bones of the fingers where they form the first joint, being inserted near the centre of motion, move the ends of the fingers with very great velocity. They are the organs which give the hand the power of spinning, weaving, engraving; and as they produce the quick motions of the musician's fingers, they are called by anatomists *fidicinales*.

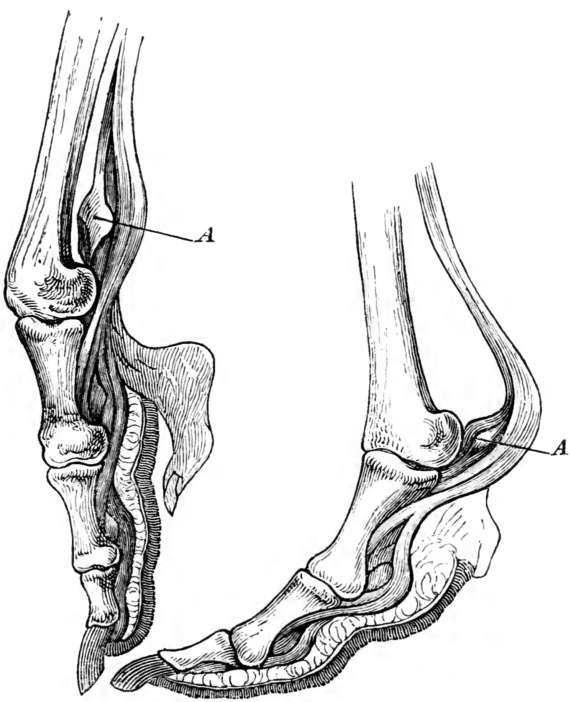
But there is another use which the small

muscles in the hand serve. In grasping with the hand, the strength with which it closes must be very great, when all the muscles are combined in action: the amount of this power is exhibited when we see a sailor hanging by a rope, and raising his whole body with one arm. What then must be the pressure upon the hand? It would be too much for the texture even of bones and tendons, and certainly, for the blood vessels and nerves, to sustain, if the palms of the hands, the inside of the fingers and their tips, were not guarded by cushions beneath the skin. The elastic pad in the foot of the horse, camel, or ostrich, is not a whit more appropriate than the fine elastic texture of the hand. To add to the efficacy of this yielding but strong padding on the hand, a muscle is provided which runs across the palm, and more especially supports the cushion on the inner or ulnar edge: it acts powerfully as we grasp; and it is this muscle which, by raising the edge of the palm, hollows it, and adapts it to lave water, forming the cup of Diogenes.

Whilst the cushions on the ends of the fingers defend them in the powerful actions of the hand, we shall presently see that they are useful also in subservience to the organ of touch; conferring a power of receiving impressions, which the utmost delicacy of the nerves themselves could not bestow.

The projection of the heel in the human foot,

and the prominence of the knee pan, are provisions for increasing, by mechanical adjustment, the power of the muscles. By such means the place of insertion of the muscle is removed to a distance from the centre of motion in the joint, and the lever power thus obtained is added to the force of the muscle. The principle is maintained, and the demonstration more easy, in the joints of some animals, as in the hock of the horse; and we have a beautiful instance of it in the foot of the ostrich. Where the flexor tendons pass behind the several joints of the foot,



the heads of the bones are enlarged; which throws the tendons off from the centre of motion. But there is an additional provision still. A loose pendulous body hangs between the tendons and bone at each of these joints; and it plays upon the bones in such a manner, that at the utmost degree of extension of the foot, when the bird requires to use all its power of muscular exertion to bend it again, this body is introduced to throw the tendons further backwards, and to add remarkably to the lever power. This body, A., is shaped like a wedge, with grooved surfaces to correspond with the bone before, and the tendon behind: and it is suspended by an appropriate muscle, by which it is raised, like a bolt, after having served its office of throwing off the tendons from the centre of motion. In addition, it may be seen in the sketch, that where these tendons pass behind the joints, they are thickened and hardened into cartilages, so that the bolt operates more effectually in directing them backwards, and producing the projection, equivalent to that of the heel or the hock.* These are the means by which "she lifteth up herself on high, and scorneth the horse and his rider."

After the many illustrations which we have offered from mechanics, the muscular power itself must be a subject of surprise and admiration. Gravity, the expansion and condensation

* I am indebted to Mr. Shaw for these interesting demonstrations of the ostrich's foot.

of steam, the production of gases, the spring or elasticity of material, or all these combined, could not have answered the varied offices performed by this one property of life, the muscular contractility. The irritable and contractile fibre, of which the muscles are composed, when chemically considered, does not differ from the fibrine of the blood, but from its being endowed with this property of contraction, and adapted with "mechanical ingenuity," it fulfils a thousand distinct purposes, in volition, breathing, speaking, digestion, assimilation, circulation; and it is modified in all these functions to the wants and condition of every class of animals.

From what the reader already understands of the conformity subsisting among all the parts of an animal body, he will readily comprehend that a perfect relation must be established between the bones and the muscles: that as the bones of different animals exhibit a variety in their size, relative position, and articulations, so must there be an adaptation of the muscles. Accordingly, we sometimes find the muscles separated into smaller, and sometimes consolidated into more powerful masses. To the anatomical student, the mode of demonstrating the muscles of the human hand and arm, becomes the test of his master's perfection as a teacher. When they are taken successively, just as they present themselves in the arm, nothing can be

more uninteresting, tedious, and difficult to attend to, than such a demonstration: but when

they are taught with lucid arrangement, according to the motions performed by the distinct

groups of muscles, it is positively agreeable to find how much interest may be given to the subject.

It would be foreign to the object of this work to introduce such demonstrations here. Yet it is very remarkable that the muscles of the arm and hand should resemble so closely the muscles of the fore extremity of certain animals—of the lion, for example. I have added a sketch of the muscles of the lion's fore leg and paw; and we see that their shape bears a great resemblance to the fore-arm of man. The flexors, extensors, pronators, and supinators, in the brute, are exactly in the same place, and have the same relations to each other, which the student of anatomy is taught to observe with so much interest in the human arm. This example is sufficient to show how accurately the arrangement of the muscles conforms to the structure of the bones; and that in proportion as the bones of the extremity of any animal resemble those of the human arm, in their shape and power of motion, so will the muscles—another proof of the extent of the system of relations established in the animal frame.

There is one circumstance more which should not be omitted in the comparative anatomy of these muscles, as it exhibits another instance of conformity in their structure to the offices which they have to perform. We have just stated that

the power of contraction is a vital property. The continued action of a muscle, therefore, exhausts its vitality. Now, to support that action, when inordinate, there must be a more than usual provision for the supply of this living power to the muscle :—there must be a means of increasing or maintaining the circulation of the blood within it which is the source of all vital power.

In the *loris tardigradus** it has been observed that the axillary and femoral arteries, the great arteries of the anterior and posterior extremities, present this peculiarity—the main vessel is subdivided into a number of equal-sized cylinders, which again unite to form a single trunk, previous to the distribution of the proper branches to the muscles.† As this subdivision of the trunk of the vessel produces a retardation of the blood, it has been argued that it is adapted to the slow motion of the animal. On the contrary, I believe it to be a provision for long continued action. The animals which possess this peculiarity in their circulation are not more remarkable for the slowness of their progression, than for the tenacity of their hold : their extremities are long, and their muscles powerful, either for sustaining the animal by grasping the branches of trees, or for digging. But surely the strength

* See the Appendix, Division I. Quadrumana.

† There is some doubt as to the reunion of the vessels.

of the muscles cannot be maintained by retarding the circulation of the blood: as it is a principle universally admitted, that the expenditure of arterial blood always bears a proportion to the vital force employed.

Buffon tried to make a dog amphibious, by immersing the puppy, before it had breathed, in tepid water. One of our own physiologists thought it possible to make a tardigrade animal out of a vivacious spaniel, by putting ligatures upon the arteries which go to its limbs, and forcing the blood to take a circuitous course and by numerous channels, to the muscles, as in the loris tardigradus. We need hardly say that these experiments failed. They were undertaken in a misconception of the nature of the living properties of muscles; which are more finely adjusted than any thing in the mere mechanism of the body. Every muscle of the body has its prescribed mode of action, from the unwearied irritability causing the incessant motion of the heart, to the simple effort of the muscle which guides the pen. Some muscles are ever in action, with but short intervals of rest; others act in regular succession: some are under the will, others withdrawn from it; some act quickly, as the heart, others slowly, as the stomach; but these are original endowments, and do not result from the force or languor of the circulation of the part.

Were the arteries of the living body like rigid tubes, and the laws of the circulation the same as those of hydraulics, a subdivided and tortuous artery would certainly be the means of retarding the course of the blood. But it is impossible to believe that the circulation of the blood can be performed according to the same laws which govern the flow of water in dead tubes. The artery is dilatable; it contracts with a vital force; and both the dilatability and the contractility of arteries are subject to the influence of the living principle. When, therefore, the artery of a limb is divided into four or five vessels, and these are tortuous, as in the sloths, the result is a greater capacity of dilatation, and a greater power of contraction; and these being vital operations, are subject to be influenced and adjusted according to the necessity for the increase or diminution of the circulation. If such a peculiarity in the form of the vessels in the extremities of these animals retard the blood, it can only be during repose; for, on excitement, so far from retarding, it must bestow a remarkable power of acceleration. I conclude, therefore, that this variety of distribution in the arteries is a provision for an occasional greater activity in the muscles of the limb, and for forcing the blood into contact with the fibres, notwithstanding their long continued action and rigidity. We have seen, in the preceding chapter, that the same animal which at one time moves out its paw as

slowly as the hand of a watch, at another, when seizing its prey, acts with extreme rapidity: consequently, we cannot admit the inference that the tortuous and subdivided artery is a provision for languid motions.

In speaking of the arteries which go to the hand, it may be expected that we should touch on a subject, formerly a good deal discussed, whether the properties of the right hand, compared with the left, depend on the course of the arteries: for it is affirmed that the superiority of the right arm is owing to the trunk of the artery which supplies it, passing off from the heart so as to admit the blood more directly and more forcibly into the small vessels of the arm. This is assigning a cause altogether unequal to the effect, and presenting too confined a view of the subject: it partakes of the common error of seeking in the mechanism the explanation of phenomena which have a deeper origin.

There is an universal consent, among all nations, to give the preference to the right hand over the left. This cannot be a conventional agreement: it must have a natural source. For the conveniences of life, and to make us prompt and dexterous, it is pretty evident that there ought to be no hesitation which hand should be used, or which foot should be put forward; nor is there, in fact, any such indecision. Is this readiness taught, or is it given to us by nature?

Sir Thomas Brown says, if the right side were

originally the most powerful in man, we might expect to find it the same in other animals. He affirms that squirrels, monkeys and parrots feed themselves with the left leg rather than with the right. But the parrot may be said to use the strongest foot where most strength is required; that is in grasping the perch and standing, not in feeding itself.

That the preference for the right hand is not the result of education, we may learn from those who by constitution have a superiority in the left. They have a difficulty in accommodating themselves to the modes of society: and although not only the precepts of parents, but every thing they see and handle conduces to make them choose the right hand, yet, will they rather use the left.

It must be observed, at the same time, that there is a distinction in the whole right side of the body, as well as in the arm: and that the left side is not only the weaker, in regard to muscular strength, but also in its vital or constitutional properties. The developement of the organs of action and motion is greatest upon the right side, as may at any time be ascertained by measurement, or the testimony of the tailor or shoemaker. Certainly, this superiority may be said to result from the more frequent exertion of this side; but the peculiarity extends to the constitution also; and disease attacks the left ex-

tremities more frequently than the right. In opera dancers, we see that they execute their most difficult feats on the right foot. But the preparatory exercises of these performers better evince the natural weakness of the left limb; they are obliged to give double practice to it, in order to avoid awkwardness in the public exhibition; and if they neglect these exercises an ungraceful preference will be given to the right side. In walking behind a person, it is seldom that we see an equalized motion of the body; and if we look to the left foot, we shall find that the tread is not so firm upon it, that the toe is not so much turned out, and that a greater push is made with the right foot. From the peculiar form of woman, and from the elasticity of her step resulting more from the motion of the ankle than of the haunches, the defect of the left foot, when it exists, is more apparent in her gait. No boy hops upon his left foot, unless he be left handed. The horseman puts the left foot in the stirrup and springs from the right. We think we may conclude, that the adaptation of the form of every thing, in the conveniences of life, to the right hand, as for example the direction of the worm of the screw, or of the cutting end of the auger, or the shape of other tools or instruments, is not arbitrary, but is related to a natural endowment of the body. He who is left handed is most sensible to the advantages of this

adaptation, whether in opening the parlour door, or opening a pen-knife. On the whole, the preference of the right hand is not the effect of habit, but is a natural provision, and is bestowed for a very obvious purpose: and the property does not depend on the peculiar distribution of the arteries of the arm—the preference is given to the right foot, as well as to the right hand.*

* There is a pleasant and ingenious epistle by Dr. Franklin in which the left hand is personated and is made to contend for equal rights.—She complains of being suffered to grow up without instruction—that she has no master to teach her writing, drawing, and suitable accomplishments: that, on the contrary, she is left totally without exercise, but for the sympathy of her sister. To the countrymen of Dr. Franklin the study of the subordination of the organs of the animal frame, is not altogether unsuited.

CHAPTER V.

THE SUBSTITUTION OF OTHER ORGANS FOR THE HAND.

After having examined how one instrument, the hand, is modified and adapted to a variety of purposes in different animals, it only remains for elucidating it further, to contrast the hand with its imperfect substitutes in other creatures. I might, indeed, have derived some of the most curious examples of instruments suited for similar purposes with the hand and fingers of man from the insect tribes; but I have intentionally confined this inquiry to the higher classes of animals.

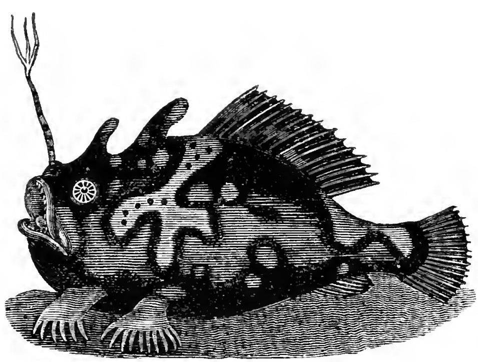
The habits of some fishes require that they should cling firmly to the rocks or to whatever is presented to them as a means of support. Their locomotive powers are perfect; but how are they to become stationary in the tide or the stream? I have often thought it wonderful that the salmon or the trout, for example, should keep its place, night and day, in the rapid current. In the sea, there are some fishes especially provided with means of clinging to the

rocks. The lump-fish, *cyclopterus lumpus*, fastens itself by an apparatus which is on the lower part of its body. The sucking fish, *remora*, has a similar provision on its back, by which it attaches itself to the surface of the shark, or to whatever is afloat; and, of course, to the bottoms of ships. The ancients believed that this fish was capable of stopping a ship under sail, and Pliny, therefore, called it remora. We must admire the means by which these fishes can retain their proper position in the water, without having to cling either by their fins or their teeth, or being prevented making efforts to seize their food.* The apparatus by which the lump-fish and remora attach themselves, resembles a boy's sucker: the organ is pressed against the surface, to which the creature is about to fix itself: the centre is then drawn upon by muscles, in the same

* In the Mollusca and Zoophytes, we find many instances of animals holding on against the force of tide or current. The Actiniæ fix themselves to rocks and shells; and some, as the sea carnation, hang suspended from the lower surface of projecting rocks, resembling the calyx of a flower. By the elongation of their tentacula, they expand and blow out like a flower; but these, instead of being petals, are prehensile instruments, by which the animal draws whatever food floats near it into its stomach. The byssus of the muscle is a set of filaments proceeding from the joint which retains the shell at anchor, and prevents it drifting or rolling with the tide: these filaments are the secretion of a gland; and they are fixed to the rock, whilst the gland preserves the hold at the other end. The shell of the oyster is itself cemented to the rock.

manner as the sucker is drawn with the cord, and thus a vacuum is made. Dr. Shaw tells us, that on throwing a fish of the species cyclopterus lumpus into a pail of water, it fixed itself so firmly to the bottom, that by taking hold of it by the tail, he lifted the pail off the ground, although it contained some gallons of water.

In the cuttle-fish we see a modification of this apparatus: the suckers are ranged along their feelers or arms, and become instruments of prehension and of locomotion. They are capable of being turned in all directions, either to fix the animal, or to drag it from place to place. In the Indian seas, these creatures become truly terrific both from the length of their arms, which extend to eight or nine fathoms, and from the firmness with which they cling.



There is another fish, which we should expect from its name to be able to perform strange an-

tics; it is called the harlequin angler.* Its appearance is grotesque and singular; the pectoral fins resemble short arms, and they are palmated at their tips.† M. Renau, in his history of fishes, affirms that he knew an individual of this species; and the expression is not so incorrect, since he saw it for three days living out of the water, walking about the house in the manner of a dog. The circumstance of its walking out of the water has some interest, from its showing that relations may subsist between organs apparently the least connected with each other. The fact of this fish living out of the water is doubted; but the form of its branchial organs, or organs for breathing, inclines me to believe that it had this power; and its habits required such a provision. In this genus, the operculum, which covers the gills, does not open to let the respired water pass off freely behind, as in most fishes; but the water is discharged by a small aperture which, in Mr. Owen's opinion, is capable of being closed by a sphincter muscle. The cavities in which the branchiæ lie are large, and this is, indeed, partly the reason of the monstrous head of this fish. Thus, it has not only its fins

* *Lophius Histrio*, from a Greek word that has reference to the process which floats like a streamer or pennant from the head.

† These fins have two bones in them like the radius and ulna; but Cuvier says that they are more strictly bones of the carpus.

converted into feet, but its gill-covers into pouches capable of containing water, by means of which the function of the branchiæ can proceed, when the water is retired; that is, when the fish lies in the mud, or in a shallow pool; for in such situations the lophius finds its food, and angles for it in a very curious manner.

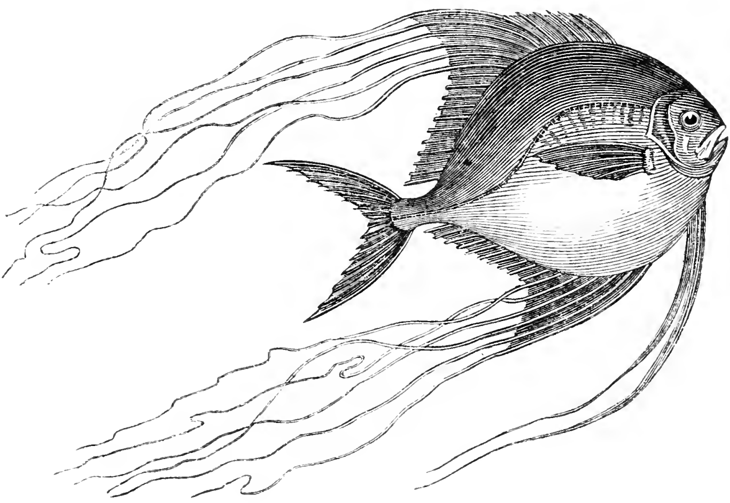
But there are other fishes that move out of the water on dry land, and even ascend trees, without being carried there by floods. Thus the *perca scandens*, can climb a tree by means of the spines of its gill-covers, and the spinous rays of its fins, whence Dr. Shaw has called it the climbing fish.*

All those creatures that have their skins protected, whether by feathers, or shells, or scales, are endowed with an exquisite sense of touch in their mouth, or in the appendages hanging from it. Fishes have *cirri* which hang from their lips, and are equivalent to the feelers or tentacula of insects and crustacea. The fishing lines of the *lophius piscatorius* are examples of these processes: and Pliny relates of this frog-like fish, that it will hide itself in the mud, and leave the extremities of its filaments alone visible, which,

* The spines of the Echinus, or Sea Urchin, are moveable; they assist in progression. They are directed towards an advancing enemy! Although these spines may be effectual for their purposes, they are to be regarded as the lowest or least perfect substitutes for the extremities.

from their resemblance to worms, entice the smaller fishes, and they become the prey of their concealed enemy.

It is surprising how varied the means are by which fishes obtain their food. The *chœtodon* (bandouliere à bec) squirts water at flies as they pass, brings them down and then feeds upon them. The *sciœna jaculatrix*, according to Pallas, possesses a similar power; and the *sparus insidiator* catches aquatic insects by the sudden projection of its snout. It is affirmed by some naturalists that the rays of the dorsal and anal fins, as in the cordonnier of Martinique (*zeus ciliaris*, le blepharis, Cuv.), are employed to grapple with or to coil round the stems of plants in order to sustain the fish.



The several offices that have been attributed

to these processes in fishes, almost implies that they must be possessed of sensibility, if not of muscular power. By anatomical investigation and experiment, some years ago I discovered that the sensibility of all the head, and of its various appendages, resulted from one nerve only of the ten that are enumerated as arising from the brain, and are distributed within and around the head. Pursuing the subject by the aid of comparative anatomy, I found also that a nerve corresponding to this, which is the fifth nerve in man, served a similar purpose in all the lower animals. In creatures which are covered with feathers or scales, or protected by shell, this nerve becomes almost the sole organ of sensibility. It is the developement of it that gives sensibility to the cirri, which hang about the mouths of fishes, and to the palpa of the crustacea and insects. It is the same nerve which supplies the tongue, and is the organ of its exquisite sensibility to touch as well as of taste. In some animals, especially in the reptiles, the tongue, by its length and mobility, becomes a substitute for these external appendages. We might have noticed before, that the tongue is an organ of prehension and of touch as well as of taste. With it the ox gathers in the herbage; and in the giraffe, it is rather curious to observe that, as the whole frame of the animal is calculated to raise the head to a great height, so is the tongue capable of projecting

beyond the mouth to an extraordinary extent, to wrap round and pull down the extreme branches of trees. The whiskers of the feline quadrupeds possess a fine sensibility, through branches of the fifth nerve, which enter their roots. Birds have a high degree of sensibility to touch in their mouths. In ducks, and all that quaffer with their bills under water, the sense is very fine, and we find, on dissection, that a branch of the fifth nerve, remarkably developed, is distributed on the upper mandible. Animals feel in the whole of their external surface; and we may say that serpents, by coiling themselves round a body, have the organ of touch all over them. Still the fifth pair of nerves in the head, or the nerve analogous to it, is the main instrument of touch in the greater number of animals where extremities are wanting. The organs may vary in their conformation; sometimes they are only delicate palpa, sometimes horny rods, and these are often possessed of muscularity, as well as sensibility; but in all, the sense of touch is bestowed through a nerve corresponding with the fifth pair—the nerve of the tongue and lips, and of the muscles of the jaws, in man.

But we may repeat, that, necessary as these appendages and this sensibility are to the existence of the animals possessing them, the imperfections which they exhibit, serve to show, by contrast, how happily the hand is constructed:

in which we perceive the sensibilities to changes of temperature, to touch, and to motion, united to a facility of motion in the joints, for unfolding and turning the fingers in every possible degree and direction, without abruptness or angularity, and in a manner inimitable by any artifice of joints and levers.

CHAPTER VI.

THE ARGUMENT PURSUED FROM THE COMPARATIVE ANATOMY. THE ANIMAL SYSTEM, AND THE REVOLUTIONS IN THE SOLID MATERIAL.

So far as we have hitherto proceeded, examining objects in comparative anatomy which from their magnitude cannot be misunderstood, we have been led to conclude that, independently of the system of parts marvellously combined to form the individual animal, another more comprehensive system exists, which embraces all animals; and which exhibits a certain uniformity in the functions of life, however different the creatures may be in form or bulk, or to whatever condition of the globe they may have been adapted. We have seen no accidental deviation or deformity; but every change has been for a purpose, and every part has had its just relation. In all the varieties, we have witnessed the forms of the organs moulded with such a perfect accommodation to their uses, and the alterations produced by such minute degrees, that all notion of external and accidental agency must be rejected.

We might carry our demonstration downward

through the lower classes of animals. For example, we might trace the different modifications of the feet of insects, from their most perfect or complex state, till they disappeared ; or, following the changes in another direction, we might trace them from their smallest beginning, to the most perfect condition of the member, where we see the thigh, leg, and tarsus represented in the fly. We might distinguish them at first as the fine cirri, like minute bristles on the bodies of worms, taking slight hold of the surface over which they creep. In the sea mouse, *(aphrodita)* we might notice these bristles standing out from distinct mammillary processes, which are furnished with appropriate muscles. Then in the *myriapodes*, the first order of insects, we might see the "many feet," and each foot possessing a distinct articulation. From that, we might pass to the insects which have a thigh, leg, and foot, with the most perfect system of flexor, extensor, and adductor muscles, possessing, in fine, all that we most admire in the human anatomy. Nay, it is more curious to observe how the feet of the true insects are again changed or modified, taking new offices—the anterior feet becoming feelers, organs of prehension, or *hands*. We must perceive, that were we to examine the delicate and curiously adapted instruments of insects, with such an object, it would be easy to trace almost every part through a succession of modi-

fications. Among the *vertebrata*, we have seen the hand become a wing or a fin; so might we discover an opposite change in the wing of an insect. If we began with a fly, which has its two delicate and perfect wings incased and protected, we should find that the covers were raised so as to admit of the ready expansion of the wings. In another, the cover itself or case would be seen converted into a wing; and the fly would be characterised by having four wings. Proceeding to a third example, we should discover that this anterior wing was larger and more perfect than the posterior. In the fourth specimen, we should find that the posterior wings had disappeared, and that it had only two perfect ones. If we continued the examination further, the next specimen would present an insect deprived of wings altogether. These are not freaks of nature, but new forms of the body; new appendages required for a different poising of the fly in its flight. They are adaptations succeeding each other in that regular series which we have observed to obtain in the larger animals, and where the intention cannot be mistaken.

A very natural question will force itself upon us, how are those varieties to be explained? The curious adaptation of a member to different offices and to different conditions of the animal has led to a very extraordinary opinion, in the

present day,—that all animals consist of the same elements. It would be just to say that the material of which animals are formed consists of the same chemical elements, and that this material is attracted and assimilated by the performance of the same vital functions, in every species of animal, however differing in form and structure. But by the elements here alluded to, the authors mean certain pieces, which enter into the structure of the body; and which they suppose, by being transposed and differently arranged, give rise to the varieties in the forms of animals. They illustrate their views by the analogy of the building materials of a house. If these materials, they say, are exhausted in the ornamental parts, as the portico and vestibule, there must be a proportionate limitation of the apartments for the family. This new theory has been brought forward with the highest pretensions. The authors of it have called upon us to mark the moment of its conception as the commencement of a new æra! They speak of the "elective affinities of organs," "the balancing of organs," "a new principle of connection," and a "new theory of analysis." The hypothesis essentially is this, that when a part, which belongs to one animal, is missed in another, we are to seek for it in some neighbouring organ. On such grounds they affirm, that this surpasses all former systems as a means of discovery.

Now, the perfection or aggrandizement of any one organ of an animal is not attended with the curtailment or proportional deficiency of any other. Perhaps the supporters of this theory dwell too much upon the bones; but even in them, we shall show that the system is untenable. In the meantime, we may ask, is the addition of new parts in connection with the stomach, making this organ highly complex, as in ruminating animals, attended with a shortening of the intestinal canal, or increased simplicity in its structure? On the contrary, is not a complex stomach necessarily connected with a long and complicated intestine? Does a complex intestinal canal throughout all its course, render the solid viscera which are in juxtaposition to it imperfect? Is there any defect in them, because the organs of digestion are perfect or complicated? Does the complex heart imply a more simple, or a more perfect condition of the lungs? In short, as animals rise in the scale of existence, do we not find that the systems of digestion, circulation, respiration, and sensation bear ever a proportional increase? Is there any instance of an improvement in one organ thrusting another out of its place, or diminishing its volume? As to the osseous system, were we to follow these theorists into the very stronghold of their position, the bones of the skull, where the real intricacy of the parts allows some scope for ingenuity,

we might show how untenable was the principle that they had assumed. But we prefer confining ourselves to our own subject.

In the higher orders of the vertebrata, we have already stated that the bones of the shoulder perform a double office; that they have an important share in the act of respiration, whilst they afford a perfect foundation for the motions of the extremity. Now, let us take an instance where the mode of respiration of the animal is inconsistent with what we may term the original mechanism of the bones of the shoulder. In the batrachian order, the ribs are wanting. Where then are we to look for them? Shall we follow a system that will inform us, if a bone be wanting in the cavity of the ear of the bird, that we are to seek for it in the jaw; and yet will not point out, when a whole class of animals is deficient of thirty-two ribs, where these are to be found, or how these elements are built up in other structures? By adopting, on the contrary, the principle that parts are formed or withdrawn, with a never failing relation to the function which is to be performed, we can comprehend, if the compages of the chest be removed, to suit the peculiarities of the animal, and the shoulder be consequently deprived of support, why the bones to which the extremity is fixed, should be expanded and varied both in their form and articulation, so as to fulfil the main object of a shoulder, that

of giving security and a centre of motion to the arm.

With respect to the instance which we have accidentally noticed, of the mechanism of the jaw in birds, and which is brought forward so vauntingly as a proof of the excellence of the theory above referred to, it does, indeed, prove the reverse of what is assumed. The only effect of this hypothesis is to make us lose sight of the principle which ought to direct us in the observation of such curious structures, and to miss the conclusions to which an unbiassed mind would otherwise come.

The matter to be explained is simply this. The chain of bones in the ear, which is so curiously adapted in the mammalia to convey the vibrations of the membrane of the tympanum to the nerve of hearing, is not found in the organ of hearing in birds; but there is substituted a mechanism entirely different. The supporters of this theory choose to say that it is the incus, one of the four bones of the chain, which is wanting in the bird: and where is it to be found?—they ask. Here in the apparatus of the jaw or mandible; in that bone which is called *os quadratum*.

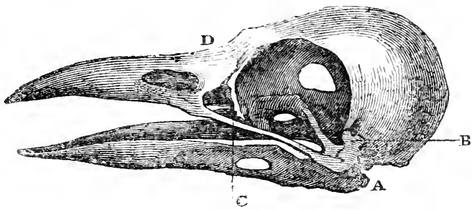
I believe that the slight and accidental resemblance which this bone (B.) (see figure p. 173) in the bird, has to the incus in man, is the real origin of this fancy. But let us follow a juster mode of reasoning, and see how the hypothesis

in question obscures the beauty of the subject. The first step of the investigation ought to be to inquire whether from the want of this bone, there is any imperfection in the hearing of birds. That is easily answered—the hearing of birds is most acute; the slightest noise alarms them; and the nightingale or other bird of song, in a summer evening, will answer to the note of his rival, when he is out of our hearing. We have next to observe another peculiarity in the organ—the want of an external ear; the presence of which would be at variance with all that we most admire in the shape of the bird, and in the direction of the feathers, as conducing to its rapid passage through the air. With this obvious defect of the external ear, can we admit that the internal ear is also imperfect, notwithstanding the very remarkable acuteness of hearing, which we know does result from this internal structure alone? Now although we do, in fact, find a different structure in the ear of the bird from that of the mammalia, yet nothing is wanting. The *columella* is a shaft of bone of exquisite delicacy, which is extended from the outward membrane of the ear to the labyrinth, or proper seat of the nerve of hearing; and it occupies the same place and performs the same office as the chain of four bones which belongs to the ear of mammalia. But we have no authority for affirming that the incus is here wanting, more than any other bone

of the chain. The sense of hearing is enjoyed in as exquisite a degree by birds as by quadrupeds: the organ of the sense is not imperfect, but is adapted to a new construction, and a varied apparatus—that is, it is suited to the condition of the bird: and there is no accidental dislocation or substitution of something less perfect than what we find in other classes of animals.

If we now look to the structure of the mandibles of the bird, and to the use which this os quadratum, supposed by the upholders of the theory to be transposed from the ear, serves in the apparatus for moving them, we shall find as curious an example, though a somewhat grosser one, of mechanical relation. The bill of the bird, in some degree, pertains to our subject, as it is the organ of prehension and of touch. It is withal a fly trap—hence, its motions must be rapid: and the velocity is increased by the most obvious means imaginable,—that is, by giving motion to both mandibles, instead of to one. When a dog snaps, he throws back his head, and thereby raises the upper jaw at the same time that the lower jaw is dropped; but these are slow and clumsy motions, performed by the muscles of the neck as well as by those of the jaws; and the poor hound makes many attempts, before he can catch the fly that teazes him. But a swallow or a fly-catcher makes no second effort; the apparatus of prehension which it possesses, is so

admirably suited to the liveliness of its eye and to its instinct. The adaptation of the instrument for giving such rapidity of motion results from this, that the muscles which depress the lower



mandible, elevate by the same effort the upper one: A. is a process of the lower mandible, projecting behind the centre of motion; the muscle which is attached to this process, therefore, causes the point of the bill to descend when it acts: but the *os quadratum* (B.) situated between the lower mandible and the skull, is pressed upon at the same time: now a shaft or process (C.) from this bone, projects forwards, and has its anterior extremity fixed against the upper mandible: accordingly, when the muscle acts, and the os quadratum receives the pressure of the lower mandible, this process is thrust forwards, like a bolt, against the upper mandible, which moves upon the skull at (D.): hence the upper mandible is elevated, at the same time that the lower is depressed.* Here, then, is a

* There is another process of the os quadratum, which, from being directed more internally, assists in raising the upper mandible.

piece of mechanism as distinct as the lock of a gun, and manifestly intended, as we have said, to give rapidity to the motions of the bill. Now, whether is it nearer the truth to consider this as a new apparatus, suited to the necessities of the creature, or to look upon it as an accidental result of the introduction of a bone, which in its proper office has nothing to do with the jaw?

But we have wandered somewhat from our subject. We have hitherto examined the bones of the shoulder, or those of the extremity nearest to the trunk. We may now pursue the inquiry by noticing those more remote from it. In the bones corresponding with those of the hand, we have seen that the same system was preserved, but variously modified so as to be adapted to every possible change in office. Now as it is insisted that the number of parts continue the same, what can be said with regard to the bones of the paddle, in the saurian, and chelonian reptiles? These, as in the ichthyosaurus for example, consist of sixty or seventy polygonous bones; whilst in the horse there are only fifteen bones; and in man, twenty-seven. Yet, notwithstanding there are so many bones in the paddle, there is only the proper complement in the part corresponding with the arm and forearm. If the system fail us in such an obvious instance as this, with what confidence can we prosecute the inquiry as to the analogy of the

intricate bones of the spine and head, under its guidance?*

In seeking assistance from the works of distinguished naturalists, we do not always find indications of that disposition of mind prevailing, which we should be apt to suppose was a necessary result of their peculiar studies. We do not discover that combination of genius with sound sense, which distinguished Cuvier, and has been the characteristic of all the great men of science. It is, above all, surprising with what perverse ingenuity some will seek to obscure the conception of a Divine Author, an intelligent, designing, and benevolent Being, and clinging to the greatest absurdities, will rather interpose the cold and inanimate influence of the mere "elements," in a manner to extinguish all feeling of dependence in our minds, and all emotions of gratitude.

Some will maintain that all the varieties in animated beings are merely the result of a change of circumstances influencing the original animal; that new organs have been produced by a desire, and consequent effort, of the animal, to stretch and mould itself into a shape suitable to the condition in which it is placed,—that, as the leaves of a plant expand to light, or turn to the sun, or as the roots shoot to the appropriate soil,

* See Additional Illustrations, *On the position of the Head, &c.*

so do the exterior organs of animals grow and adapt themselves. We shall presently find that an opinion has prevailed that it is the organization of animals which has determined their propensities; but the philosophers of whom we are now speaking, imagine the contrary,—they conceive that, under the influence of new circumstances, organs have accommodated themselves, and assumed their particular forms.*

It must be here remarked that there are no

* According to *Lamarck*, time, and favourable circumstances, are the means which *Nature* employs to give existence to all its productions. The circumstances alluded to, are climate, temperature, and the surrounding elements: as to the time, he allows no bounds. The bird which must seek its nourishment in the water, stretches its toes, and in time, the membranes extend between them, and the foot is perfected, as we see them in the duck. But the toes of the bird that perches on the branch have the points lengthened and hooked to embrace the twig. The bird which wades, and either cannot swim, or is unwilling to put its body in the water, extends its feet to obtain its food, and in time those feet and limbs are lengthened, so that the body is raised, as it were, on stilts. By a similar process of gradual developement, he would persuade his readers, that the oranoutang has shortened his arms, lost his tail, and broadened his feet, and has taken the stature and bearing of a human being.

That a man, in jest, or in mere idleness, or to provoke discussion, should have given expression to such fancies, is probable: but that any one should have published them, as a serious introduction to a system of natural history, is, indeed, surprising. It is a miserable theory, to which we can only conceive a man driven by the shame, or fear, of being thought to harbour the belief of vulgar minds.—See the Système des Animaux sans Vertèbres: discours d'ouverture, p. 15.

instances of the production of new organs, by the union of individuals belonging to different species. Nor is there any foundation, in observation, for the opinion that a new species may be formed by the union of individuals of different families. But it is contended, that, although the species of animals have not changed in the last 5000 years, we do not know what may have been the effect of the revolutions in the globe before that time; that is, previous to the present condition of the world. On subjects of this nature, however, we must argue from what we know, and from what we see.

We do, however, perceive surprising changes in the conformation of the same animal. Some of these are very familiar to us. But they all show a foreknowledge, and a prospective plan,—an alteration gradually taking place in preparation for a new condition, never consequent upon it. It will be sufficient for our purpose, if we take the highest and the lowest examples. Man has two conditions of existence in the body. Hardly two creatures can be less alike than an infant and a man. Now, the whole of his fœtal state is a preparation for birth. My readers would not thank me, if I were to explain how necessary the proportions and forms of the infant, as contrasted with those of the full grown man, are to his being born alive. Yet nothing would be so easy to demonstrate. Every one may see

that from the moment of birth, a new impulse is given to the growth, so that finally the proportions of the body undergo a change, and are adapted to the state of perfect manhood, especially to man's erect posture. Few, however, are aware that the fœtus has a *life* adapted to its condition ; and that if the confinement in the womb were protracted beyond the appointed time, it would die !—from no defect of nourishment, but simply because the period has arrived for a change in its whole economy !

Now, during the long period of gestation, all the organs are forming ; the lungs are becoming perfected, before the admission of air—new tubes are in the process of being constructed, before the flood-gates which are to admit the blood, are opened. But there are finer, and more curious, provisions than these. If we take any of the grand organs, as the heart, or the brain, and examine it through all its gradations of change in the embryo state, we shall recognise it, at first, as simple in its form, then gradually developing, and finally assuming the peculiarities which distinguish it. So that it is affirmed, and not without the support of a most curious series of observations, that the human brain, in its earlier stage, resembles that of a fish : as it is developed, it resembles more the cerebral mass of the reptile ; in its increase, it is like that of a bird ; and slowly, and only after birth, does it assume the proper

form and consistence of the human encephalon. But in none of all these changes to which man is subject, do we ever see the influence of the elements ; or of any other cause, than that the order of his developement has been so predestined.

If we were to omit the thousand instances to be gathered from the intermediate parts of the chain of animal existence, and were to examine, in the lowest link, the metamorphosis that takes place in insects, the conclusion would be the same. For example, if we take the larva of a winged insect, we shall perceive in the arrangement of its muscles, and the distribution of its nervous system, all the requisite provisions for its motion over the ground. But if, anticipating its metamorphosis, we dissect the same larva immediately before the change, we shall find a new apparatus in progress towards perfection. The muscles of its many feet are then seen decaying ; the nerves to each muscle are wasting ; a new arrangement of muscles, with new points of attachment, directed to the wings instead of to the feet, is visible ; and a new distribution of nerves, accommodated to the parts which are now to be put in motion is distinctly to be traced. Here is no budding and stretching forth of the organs, under the influence of the surrounding elements ; but a change operated on all the economy, and prospective, that is, in reference to a condition which the creature has not yet attained.

These facts countenance the conclusion drawn from the comparative anatomy of the hand and arm—that with each new instrument, visible externally, there are a thousand internal relations established: the introduction of a new mechanical contrivance in the bones or joints, infers an alteration in every part of the skeleton; a corresponding arrangement of all the muscles; that the nervous filaments, laid intermediate between the instrument and the centre of life and motion, have an appropriate texture and distribution: and, finally, we shall discover, as we proceed, that new sources of activity must be created, in relation to the new organ, otherwise the part will hang an useless appendage.

It must now be apparent that nothing less than the Power which originally created, is equal to effect those changes on animals, which adapt them to their conditions: and that their organization is predetermined; not consequent on the condition of the earth or of the surrounding elements. Neither can a property in the animal itself account for the changes which take place in the individual, any more than it can for the varieties in the species. Every thing declares the diversity of species to have its origin in distinct creations, and not to be owing to a process of gradual transition from some original type. Any other hypothesis than that of new creations of animals, suited to the successive changes in the

inorganic matter of the globe—the condition of the water, atmosphere, and temperature—brings with it only an accumulation of difficulties.

We ought not to omit bringing into the argument, to fortify what we have said, a series of changes of structure, of a different nature altogether from those which we have been considering. We mean the revolutions that are taking place, during the whole life and without a pause, in the material composing the frame of every individual animal. No description of the mechanical parts of the living body, not even the account of the organs of the senses, with their relations to external objects, can convey an idea of the power that is continually in operation, equal to that which we obtain by contemplating the influence of *life*, in collecting, arranging, and incessantly changing the material of the frame.

Astounded by the magnitude of natural objects, bewildered by seeing neither beginning nor end, and witnessing only processes of decay which would almost persuade us that all objects in nature were given up to a power of destruction, how useful must it be to have the proofs, in the microcosm of the living body, that a system may be continued, even when every portion of the substance suffers change.

Life preserves the materials of the body free from the influence of those affinities which hold

the inorganic world together; and it not only does this, but substitutes other laws. None of the wonders of the microscope are greater than what are presented by looking to the early rudiments of an animal, it may be the largest that inhabits the earth. This portion of matter will exhibit an appearance of being homogeneous, transparent, soft, and like a jelly; and only a single pulsating point will be visible in it. What might be seen by employing some of the newly discovered properties of light, it is impossible to say; as polarized light discloses, in mineral bodies, a structure which cannot otherwise be perceived, so we may imagine that a new power bestowed upon the eye might discover a distinction of parts in what seems an uniform drop of jelly. But the greatest source of wonder is, that this mass possesses within it a principle of life—and that it is not only ordered what this influence shall perform, in attracting matter, and building up the complex structure of an animal body; but even the period of the existence of the animal is from its beginning defined. This life may be limited to a day, and truly ephemeral; or be protracted to a hundred years: and the period is adjusted, as perfectly as the mechanism and structure itself, to the condition of existence and enjoyment of the individual, and to the continuance of the species.

Nothing is more remarkable than the slight

hold by which this life is retained by some of these organic structures, and the tenacity of life possessed by others. Slight changes of temperature or of moisture will annihilate some; whilst others may be dried up into dust, or ribbed in ice, and after years will admit of resuscitation. And if, instead of contemplating how the variety of the term of life allotted to different animals is adapted to their place, we think of ourselves, we shall conclude that in no living creature is it so obviously designed that the stages of life shall be distinctly marked—so that the tenure by which we hold that life may be continually before us.

But to our argument;—during all the progressive changes of life, the material of the animal body is ever new. The poet's picture of the last stage of man's life is not a true one. If man totters under the burthen of years, the simile of a ruin is inapplicable. The material of his frame is not different, and not older, than that of a child—it is ever decaying, ever renewing, whilst the office of digestion and assimilation goes on at all. The difference of the activity with which this change in the material of the body is wrought, compared with that of the child, may be as a week to a day; but here is not the cause of the grey hairs, the faded cheek, and the feeble step. This is the stamp which the Creator has intended should be deciphered and interpreted.

When the many beautiful fabrics built up

within the animal body are passed under review, and it is proved that they are not permanent in their structure, but, on the contrary, are ever changing, and ever forming anew,—moreover, when it is learned that these textures are the product of an energy, or life, which continues uniform in its operation, whilst all the materials upon which it works are changing—who can hesitate to believe that the revolutions occurring in the inorganic matter around us are superintended by a presiding Power? The difficulty of comprehension here must be attributed to the partial view which we obtain of these changes; because the fulfilment of them extends into periods far beyond our measure of time. Nevertheless, we cannot doubt that such a Power does overlook them; and we must acknowledge that a balance is preserved, and that order and harmony prevail.

CHAPTER VII.

OF SENSIBILITY AND TOUCH.

We find every organ of sense, with the exception of that of touch, more perfect in brutes than in man. In the eagle and the hawk, in the gazelle and in the feline tribe, the perfection of the eye is admirable;—in the dog, wolf, hyæna, as well as in birds of prey, the sense of smelling is inconceivably acute; and if we should have some hesitation in assigning a more exquisite sense of taste to brutes, we cannot doubt the superiority of that of hearing in the inferior animals. But in the sense of touch, seated in the hand, man claims the superiority; and it is of consequence to our conclusion that we should observe why it is so.

It has been said that, accompanying the exercise of touch, there is a desire of obtaining knowledge; in other words, a determination of the will towards the organ of the sense. Bichat says that touch is active, whilst the other senses are passive. This opinion implies that there is something to be understood—something deeper than what is here expressed. We shall arrive at the truth by considering that in the use of the

hand, there is a double sense exercised. In touch, we must not only feel the contact of the object; but we must be sensible to the muscular effort which is made to reach it, or to grasp it in the fingers. It is in the exercise of this latter power that there is really any effort made. There is no more direction of the will towards the proper nerve of touch, than towards any other sensible nerve. But, before entering on the consideration of the sensibility and the actions which belong to the fingers, we must attend to the common sensibility of the surface.

Besides that the common sensibility is bestowed upon the hand, as upon other parts, and some inquiry into it is necessary to complete our subject, I enter upon the examination of it the more willingly, because nothing can afford more surprising proofs than it, of design, and of benevolence in the Author of our being. However obviously the illustrations drawn from the mechanism of the body lead to this conclusion, they are not to be compared to those derived from the living endowments of the frame.

I have used the term common sensibility in conformity with the language of authors and with customary parlance; but the expressions, the "common nerves," and the "common sensibility," in a philosophical inquiry, are inadmissible. Indeed, these terms have been the cause of much of the obscurity which has hung over

the subject of the nervous system, and of our blindness to the benevolent adaptation of the endowments of that system to the condition of animal existence. Thus, it has been supposed that some nerves are more coarsely provided for sensation ; and that others are of a finer quality, and are adapted to more delicate impressions. It has been assumed that the nerve of the eye is finer than the nerve of the finger—without considering that the retina* is insensible to qualities of matter, of which the nerve of touch is cognizant. Nerves are, indeed, appropriated to peculiar senses, and to the bestowing of distinct functions; but delicacy of texture has nothing to do with this. It is not because the nerve of touch in the skin has a coarser or more common texture than the optic or auditory nerve, that it is insensible to light or to sound : the beauty and perfection of the system is, that each nerve is made susceptible to its peculiar impression only. The nerve of the skin is alone capable of giving the sense of contact, as the nerve of vision is confined to its own office. If this appropriation resulted merely from a delicacy of texture : if the retina were sensible to the matter of light only from possessing a finer sensibility than the nerve of touch, the acuteness of the sense would be a source of torment; whereas it is most bene-

* The retina is the expansion of the optic nerve within the eye.

ficently provided that this nerve shall not be sensible to pain, nor be capable of conveying to the mind any impressions but those which operate according to its proper function, producing light and colour.

The pain experienced in the eye, as from the irritation of dust, is owing to a distinct nerve from that which bestows vision; and is consequent on its susceptibility to a different kind of impression from that of the surface generally; of which more presently. We should keep in mind the interesting fact, that when surgeons perform the operation of couching, the point of the needle gives the sensation of pricking, which is an exercise of the nerve of touch, when it passes through the outer coat of the eye; but when it passes through the retina, which is the expanded nerve of vision, and forms the internal coat of the eye, it gives the sensation as if a spark of fire had been produced. The nerve of vision is as insensible to touch, as the nerve of touch is insensible to light.*

The extreme sensibility of the skin to the

* The views of the nervous system, shortly given in the text, guided me in my original experiments made twenty-six years ago: but they have been recently attributed to foreign physiologists. The ignorance of what has been done in England, may be, to strangers, an excuse for maintaining these opinions as their own; but the authors at home, who should have known what has been taught in this country, are inexcusable when they countenance these assumptions.

slightest injury, conveys to every one the notion that the deeper the wound, the more severe must the pain be. This is not the fact, nor would it accord with the beneficent design which shines out every where. The sensibility of the skin serves not only to give the sense of touch, but to be a guard upon the deeper parts; and as they cannot be reached except through the skin, and we must suffer pain, therefore, before they can be injured, it would be superfluous to bestow sensibility upon these deeper parts themselves. If the internal parts, which act in the motions of the body, had possessed a similar degree and kind of sensibility with the skin, so far from serving any useful purpose, this sensibility would have been a source of inconvenience and continual pain, in the common exercise of the frame.

Surgeons have perhaps better opportunities of advancing physiology than physicians, as they become practically acquainted with a greater number of the phenomena on which the science is founded. The surgeon who has to perform an operation by incision, when he has cut through the skin, informs his patient that the greatest pain is over. If, in the advanced stage of the operation, he is obliged to extend the incision of the skin, it is very properly considered a great awkwardness; and this not only because it proves that he has miscalculated what was necessary to the correct performance of his opera-

tion, but because the patient, bearing courageously the deeper incisions, cannot sustain the renewed cutting of the skin, without giving token of severe pain. The fact of the exquisite sensibility of the surface, in comparison with the deeper parts, being thus ascertained by daily experience, we cannot mistake the intention: that the skin may serve as a safeguard to the delicate textures contained within, by forcing us to avoid injuries. And it does afford a more effectual defence, than if our bodies were covered with the hide of the rhinoceros.

The fuller the consideration which we give to this subject, the more convincing will the proofs be that the painful sensibility of the skin is a benevolent provision; from its making us alive to those injuries, which otherwise would bruise and destroy the internal and vital parts.

In pursuing this enquiry, we learn with much interest that when the bones, or the joints, or any of the membranes and ligaments which cover them, are exposed—they may be cut, pricked, or even burned, without the patient, or the animal, suffering the slightest pain. These facts must appear conclusive; for who, on witnessing such instances of insensibility, would not conclude that the parts were entirely devoid of sensation? But when we adopt the true, the philosophical, and I may say, the religious view of the subject, and consider that pain is not conferred as an evil, but

is given, on the contrary, for benevolent and important purposes, we are prevented from terminating the investigation here.

In the first place, we must perceive that if a sensibility similar to that of the skin had been bestowed upon these internal parts, it must have remained unexercised. Had they been rendered sensible to pricking or to burning, they would have possessed a quality which would never have been useful to them ; since no such injuries could reach them, without a previous warning having been received, through the sensibility of the skin.

But, further, allowing that sensibility to pain is a benevolent provision, and is bestowed for the purpose of warning us to avoid such violence as would affect the functions or uses of the parts, we may yet inquire whether there are not certain injuries that might reach these internal parts, without the sensibility of the skin being excited. Now, of this there can be no doubt ; for the textures around the joints are subject to sprain, and rupture, and shocks, while the skin may not have been at all implicated in the accident. Accordingly, notwithstanding what has been apparently demonstrated of the insensibility of these internal parts, they must possess an appropriate sensibility, or it would imply an imperfection.

Such reflections make us recur to the experiments : and we find that the parts which are in-

sensible to pricking, cutting, and burning, are actually sensible to concussion, to stretching, or laceration.

How consistent, then, and beautiful is the distribution of this quality of life! The sensibility to pain varies with the function of the part. The skin is endowed with sensibility to every possible injurious impression which may be made upon it. But had this kind and degree of sensibility been made universal, we should have been racked with pain in the common motions of the body: the mere weight of one part on another, or the motion of the joint, would have been attended with that degree of suffering which we experience in using or walking upon an inflamed limb.

But on the other hand, had the deeper parts possessed no sensibility, we should have had no guide in our exertions. They have a sensibility limited to the kind of injury which it is possible may reach them, and which teaches us what we can do with impunity. If we leap from too great a height, or carry too great a burthen, or attempt to interrupt a body whose impetus is too great for us, we are warned of the danger as effectually by this internal sensibility, as we are of the approach of a sharp point or a hot iron to the skin.

Returning to the consideration of the sensibility of the skin, in order more fully to com-

prehend the benevolent effect of it, or in other words, its necessity to our very existence, I may be excused for stating the argument to the reader as I have delivered it in my lectures to the College of Surgeons.

" Without meaning to impute to you inatten- " tion or restlessness, I may request you to ob- " serve how every one occasionally changes his " position and shifts the pressure of the weight " of his body ; were you constrained to retain " one position during the whole hour, you would " rise stiff and lame. The sensibility of the " skin is here guiding you to do that, which if " neglected, would be followed even by the death " of the part. When a patient has been received " into the hospital with paralysis of the lower " half of the body, we must give especial di- " rections to the nurse and attendants, that the " position of his limbs be changed at short inter- " vals, that pillows be placed under his loins and " hams, and that they be often shifted. If this " be omitted, you know the consequence to be " inflammation of the parts that press upon the " bed ; from which come local irritation, then " fever and mortification and death.

" Thus you perceive that the natural sensi- " bility of the skin, without disturbing your " train of thought, induces you to shift the body " so as to permit the free circulation of the " blood in the minute vessels : and when this

"sensibility is wanting, the utmost attention of "friends and the watchfulness of the nurse are "but a poor substitute for the protection which "nature is continually affording. If you suffer "when lying on a soft bed, how could you, when "deprived of the sensibility of the skin, encoun-"ter the rubs and impulses incident to an active "life? You must now acknowledge that the "sensibility of the integuments is as much a "protection to the frame generally, as the sensi-"bility of the eyelids is to the eyes; and the re-"flection gives you a motive for gratitude, which "probably you never thought of."

The sensibility of the hand to heat, is a different endowment from that of touch. This sensibility to the varieties of temperature is seated in the skin, and is, consequently, limited to the exterior surface of the body. The internal parts of the body being of an uniform temperature, it would have been altogether superfluous to have bestowed it upon them. As we are surrounded by a temperature that is continually varying, and its extremes might cause the destruction of our frame, and as we must suit our exertions or our contrivances to sustain life against such vicissitudes, the possession of this peculiar sensibility by the surface affords another proof of there having been a foreknowledge of our condition. We might, indeed, recur to our former example, to illustrate the evils that might befal us

from the want of this sensibility. The paralytic is frequently brought to us severely burned; or with his extremities mortified through cold. A man who had lost the sense of heat in his right hand, but retained the muscular power, lifted the cover of a pan, which had fallen into the fire, and deliberately replaced it, not being conscious that it was burning hot; the effect, however, was the death and destruction of the skin of the palm and fingers. In this man, there was a continual sensation of coldness in the affected arm, which actual cold did not aggravate, nor heat in any degree assuage.*

Sensibility to heat is not only a safeguard, in as much as it is capable of becoming a painful sensation; but it is a never-failing excitement to activity and a continual source of enjoyment. And here we may remark an adaptation of the living property very different from the physical influence. Heat is uniform in its effect on matter; but the sensation varies as it is given to, or abstracted from, the living body. Cold and heat are distinct sensations; and this is so far important that without such contrast we should not continue to enjoy the sense. For in the nervous system it holds universally that variety or contrast is necessary to sensation, the finest organ

* There are certain morbid conditions of sensation when cold bodies feel intensely hot.—*Dr. Abercrombie's Inquiry into the Intellectual powers.*

of sense losing its property by the continuance of the same impression. It is by a comparison of cold and heat that we enjoy either condition.

To contrast still more strongly the sensibility of the external surface with the endowments of the internal parts, and to show how very different a property the sensibility generally is from what is suggested by first experience, and how admirably it is varied and accommodated to the functions, we shall add one other fact. The brain is insensible—that part of the brain, which if disturbed or diseased, takes away consciousness, is as insensible as the leather of our shoe! That the brain may be touched, or a portion of it cut off, without interrupting the patient in the sentence that he is uttering, is a surprising circumstance! From this fact Physiologists formerly inferred that the surgeon had not reached the more important organ of the brain. But that opinion arose from the notion prevailing that a nerve must necessarily be sensible. Whereas, when we consider that the different parts of the nervous system have totally distinct endowments, and that there are nerves, as I have elsewhere shown, insensible to touch and incapable of giving pain, though exquisitely alive to their proper office, we have no just reason to conclude that the brain should be sensible, or exhibit the property of a nerve of the skin. Reason on it as we may, the fact is so;—the brain, through which

every impression must be conveyed before it is perceived, is itself insensible. This informs us that sensibility is not a necessary attendant on the delicate texture of a living part, but that it must have an appropriate organ, and that it is an especial provision.*

To satisfy my reader on this interesting subject, I shall contrast two organs, one external and exposed, and the other internal and carefully excluded from injury.

The eye, consisting of its proper nerve of vision, and of its transparent humours and coats, is an organ of exquisite delicacy—and not only is it exposed to all the injuries to which the general surface of the body is liable, but it is subject to be inflamed and rendered opaque by particles getting into it, which are so light that they float in the atmosphere, and to the contact of which the common skin is quite insensible. Now the mechanical, and more obvious contrivance for the protection of this organ, is a ready motion of the eyelids and the shedding of tears; which tears coming, as it were, from a little fountain, play over the surface of the eye, and wash away whatever is offensive. But to regulate the action of this little hydraulic and mechanical apparatus, an exquisite sensibility is required—not that kind of sensibility which enables the eye to receive the impressions of light—but a property

* See the Sensibility of the Retina, "Additional Illustrations."

more resembling the tenderness of the skin, yet happily adapted by its fineness, to the condition of the organ.

The nerve which bestows this appropriate sensibility on the eye, is possessed of a quality totally different from that of the optic nerve. It extends over all the exterior surfaces of the eye, and gives them the peculiar sensibility which we have described. It sometimes happens that this nerve is injured and its function lost; and the consequences are very curious: smoke and offensive particles afloat in the atmosphere, rest upon the eye; or flies and dust lodge under the eyelids; but without producing sensation, and without exciting either the hydraulic or the mechanical apparatus to act for the purpose of expelling them! Yet although these objects do not give pain, they nevertheless stimulate the surfaces so as to produce inflammation; this causes opacity in the fine transparent membranes of the eye; and the organ is lost, even when the proper nerve of vision remains entire. I have seen many instances of the eye being thus destroyed for want of sensibility to touch,* and it has been curious to remark, on these occasions, that when the hand was waved before the eye, or a feather was brought near to it, the person winked; yet he did not shut his eye when rubbed by the fin-

* They are stated at length in my papers in the Philosophical Transactions, and in my work on the Nervous System.

ger, or when blood was removed from the inflamed vessels by the lancet. In those cases, when the sense of vision gave notice of danger to the organ, the patient winked to avoid it; but the sense of touch gave no alarm, and was followed by no action for the protection of the organ.

I shall present another instance of the peculiar nature of the sensibility which protects the eye. The oculist has observed that if the eye be touched by a thing as light as a feather, the muscles will be thrown into uncontrollable actions and spasms: but if the point of the finger be passed somewhat rudely between the eyelids, so as to press directly on the eye itself, he can hold the eye steady for his intended operation, and produce hardly any sensation, certainly no pain! This is one of the little secrets of the art. The Oculist can turn out the eyelids, and finger the eye in a manner which appears, at once, rude and masterly: and still the wonder grows that he can do such things, with dexterity, and without inflicting pain, when daily experience makes us sensible that even a grain of sand produces the greatest torture. The explanation is this: the eye and eyelids possess a sensibility which is adjusted to excite the action of its protecting parts against such small particles as might lodge, and inflame its fine membranes: but the apparatus is not capable of protecting the surface

against the intrusion of a stick or a stone. From such injuries the eye could not be defended by a delicate sensibility and involuntary action; it requires an effort of the will.

These details supply us with new proofs of the minute relation which is established between the species of sensibility in an organ, and the end to be attained through it. If it were not for the pain to which the eye is exposed, we should quickly lose the enjoyment of the sense of vision altogether. But we were about to institute a comparison between the eye and the heart.

The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall and consequent abscess on the side of the chest, had the interior marvellously exposed; so that after his cure, on his return from his travels, the heart and lungs were still visible and could be handled; which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth and examine his heart. "When," says Harvey, "I had paid my respects to this "young nobleman, and conveyed to him the "king's request he made no concealment, but "exposed the left side of his breast, when I saw "a cavity into which I could introduce my "fingers and thumb; astonished with the novelty, "again and again I explored the wound, and

"first marvelling at the extraordinary nature of "the cure, I set about the examination of the "heart. Taking it in one hand, and placing "the finger of the other on the pulse of the wrist, "I satisfied myself that it was indeed the heart "which I grasped. I then brought him to the "king, that he might behold and touch so ex-"traordinary a thing, and that he might perceive, "as I did, that unless when we touched the "outer skin, or when he saw our fingers in the "cavity, this young nobleman knew not that we "touched the heart!" Other observations confirm this great authority, and the heart is declared insensible. And yet the opinions of mankind must not be lightly condemned. Not only does every emotion of the mind affect the heart, but every change in the condition of the body is attended with a corresponding change in the heart: motion during health—the influence of disease—every passing thought will influence it.

Here is the distinction manifested to which we meant to draw the reader's attention. The sensibility of the surface of the eye is for a purpose, and so is the sensibility of the heart. Whilst that of the eye guards it against injury from without, the heart, insensible to touch, is yet alive to every variation in the circulation, subject to change its action, from every alteration of posture or of exertion, and is in sympathy, of the strictest kind, with the constitutional powers.

When we consider these facts, we can no longer doubt that the sensibilities of the living frame are appropriate endowments; not qualities necessarily arising from life; still less the consequences of delicacy of texture. Nor can we, I should hope, longer doubt that they are suited to the condition, and especially to the degree of exposure of each part, and destined for the protection of the different organs. We perceive that the sensibilities vary in an extraordinary manner according as they are given to external or to internal parts; as they belong to one apparatus of action or to another; and they are ever adapted to excite some salutary or necessary action. We perceive no instance of pain being bestowed as a source of suffering or punishment purely, or without finding it overbalanced by great and essential advantages—without, in short, being forced to admit that no happier contrivance could be found for the protection of the part. It is provided that the more an organ is exposed, or the greater is its delicacy of organization—the more exquisitely contrived is the apparatus for its protection, and the more peremptory the call for the activity of that mechanism: and as in such instances, the motive to action admits of no thought and no hesitation, the action is more instantaneous than the quickest suggestion or impulse of the will.

We are speaking of the natural functions of

the body. It requires a deeper consideration, and is indeed foreign to my subject, to speak of the pains which result from disease, or to reconcile those who suffer in an extraordinary degree to the dispensations of Providence. But as a witness I may speak. It is my daily duty to visit certain wards of the hospital, where no patient is admitted but with a complaint that more than any other fills the imagination with the idea of insufferable pain and certain death. Yet these wards are not the least remarkable for the composure and cheerfulness of their inmates. The individual who suffers has a mysterious counterbalance to that condition, which to us who look upon her, appears to be attended with no alleviating circumstance.

It affords an instance of the boldness with which philosophers have questioned the ways of Providence, that they have asked—why were not all our actions performed at the suggestion of pleasure? why should we be subject to pain at all? In answer to this I should say, in the first place, that consistently with our condition, our sensations and pleasures, there must be variety in the impressions. Such contrast and variety are common to every organ of sense. The continuance of an impression on any one organ, occasions it to fade. If the eye continue to look steadfastly upon one object, the image is soon lost—if we continue to look on one colour,

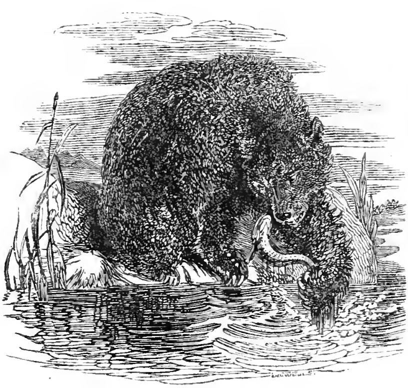
we become insensible to that colour, and opposite colours to each other are necessary for a perfect impression.* So have we seen that in the sensibilities of the skin, variations are required to render the sensations perfect.

It is difficult to say what these philosophers would define as pleasure. But whatever exercise of the senses it may be, unless we are to suppose an entire change of our nature, its opposite must also be implied. Nay, further, in this fanciful condition of existence, did anything of our present nature prevail, we must suppose that emotions purely of pleasure would lead to indolence, relaxation, and indifference. To what end should an apparatus be provided to protect the eye, since pleasure could never move us to its exercise? Could the windpipe and the interior of the lungs be protected by a pleasurable sensation, inducing a slow determination of the will—so well as by that rapid and powerful influence which the exquisite sensibility of the throat produces upon the act of respiration, or by those forcible, yet regulated exertions, which nothing but the instinctive apprehension of death can excite?

To be left to move only by the solicitations of pleasure, would be the same as to be placed where injuries would meet us at every step: and whether

* See Additional Illustrations.

felt or not, they would be destructive to life: and to suppose on the other hand, that we might move and act without experience of resistance or of pain, is the same as to suppose not only man's nature changed, but the whole of the external world also—there must be nothing to bruise the body, or to hurt the eye, nothing noxious to be drawn in with the breath; in short, it is to imagine another state of existence altogether; and the philosopher would be mortified were we to put this interpretation on his meaning. Pain is the necessary contrast to pleasure: it ushers us into existence or consciousness: it alone is capable of exciting the organs into activity: it is the companion and the guardian of human life.



CHAPTER VIII.

OF THE SENSES GENERALLY, INTRODUCTORY TO THE SENSE OF TOUCH.

Although we are most familiar with the sensibility of the skin, and believe that we perfectly understand the nature of the impressions upon it, and the mode of their conveyance to the sensorium, yet there is a difficulty in comprehending the operations of all the organs of the senses—a difficulty not removed by the apparent simplicity of that of touch.

There was a time when the enquirer was satisfied by finding in the ear a little drum and a bone to play upon it, with an accompanying nerve. This was deemed a sufficient explanation of the organ of hearing. It was thought equally satisfactory if, in experimenting upon the eye, the image of the object were seen painted at the bottom, on the surface of the nerve. But although the impression could be thus traced to the extremity of the nerve, still nothing was comprehended of the nature of that impression, or of the manner in which it was

transmitted to the sensorium. On the most minute examination of the nerves, in all their course, and where they are expanded in the external organs of the senses, they seem to be the same in substance and in structure whatever be their function. The disturbance of the extremity of the nerve, that gives rise to the sensation, whether it be a vibration upon it, or an image painted upon its surface, cannot be transmitted to the brain according to any physical laws that we are acquainted with. The impression on the nerve can have no resemblance to the ideas suggested in the mind. All that we can say is, that the agitation of the nerves of the outward senses are the signals, which the Author of nature has made the means by which we hold correspondence with the realities. There is no more resemblance between the impressions on the senses and the ideas excited by them, than there is between the sound and the conception raised by it, in the mind of a man, who, looking out on a dark and stormy sea, hears the report of cannon, which conveys to him the idea of despair and shipwreck—or between the light received into the eye and the idea excited by it, in one who, having been long in terror of national convulsion, sees afar off a column of flame, which is the signal to him of actual revolt.

Such illustrations, however, rather tend to show the mind's independence of the organ of

sense—how a tumult of ideas will be excited in the mind by an impression on the retina which may be no more intense than that produced by a burning taper. They are instances of excited imagination. But even in a common act of perception, the determined relations established between the sensation and the idea in the mind, have no more actual resemblance. How this consent, which is so precise and constant, is established, can neither be explained by anatomy, nor by physiology, nor by any mode of physical inquiry whatever.

From this law of our nature, that certain impressions originate in the mind in consequence of the operation of corresponding nerves, it follows—that one organ of sense can never become the substitute for another, so as to excite in the mind the same idea. When an individual is deprived of the organs of sight, no power of attention, or continued effort of the will, or exercise of the other senses, can make him enjoy the class of sensations which is lost. The sense of touch may be increased in an exquisite degree; but were it true, as has been asserted, that individuals can discover colours by the touch, it could only be by their feeling a change upon the surface of the stuff, and not by any perception of the colour. It has been my painful duty to attend on persons who have pretended blindness, and that they could see with their fingers: but

I have ever found that by deviating from the truth, in the first instance, they have become entangled in a tissue of deceit; and have at last been forced into admissions which demonstrated their folly and weak inventions. I have had pity for such patients, when they have been the subjects of nervous disorders, producing extraordinary sensibility in their organs—such as a power of hearing much beyond our common experience. This acuteness of sensibility, from its attracting high interest and admiration, has gradually led them to pretend to powers, greater than they actually possessed: and in such cases, it has sometimes been difficult to distinguish the symptoms of disease, from the pretended gifts which are boasted of.

Experiment proves, what is suggested by Anatomy, that each of the organs of the senses is appropriated to receive a particular class of sensations only; and that the nerves, intermediate between the brain and the outward organs respectively, are capable of receiving no other sensations but such as are adapted to their particular organs. Every impression on the nerve of the eye, or of the ear, or of smelling, or of taste, excites only perceptions of vision, of hearing, of smelling, or of tasting; not simply because the extremities of these nerves individually, are suited to external impressions, but because the nerves, through their whole course, and wherever they

are irritated, are capable of exciting in the mind the idea to which they are appropriated and no other. A blow, an impulse quite unlike that for which the organs of the senses are provided, will excite them all in their several ways; the eyes will flash fire, while there will be a noise in the ears. An officer received a musket-ball which went through the bones of his face—in describing his sensations, he said that he felt as if there had been a flash of lightning, accompanied with a sound like the shutting of the door of St. Paul's.

It is owing to this circumstance, that every nerve is appropriated to its function, that the false sensations, which accompany the morbid irritation of the nerves from internal causes, are produced, when there is in reality nothing presented externally;—such as flashes of light, ringing of the ears, bitter tastes, or offensive smells. These sensations are caused by derangement of some internal organ, most frequently of the stomach, exciting the respective nerves of sense.

Nothing affords a more perfect proof of power and design, than the correspondence that exists between the perceptions or ideas that arise in the mind, through the exercise of the organs of the senses, and the qualities of external matters: and although the manner in which the object presented to the outward sense and the idea of it are connected, must ever be beyond our comprehension, they are, nevertheless, indissolubly

united; so that the knowledge of the object, obtained by this means, is attended with an absolute conviction of its real existence—a conviction independent of reason, and to be regarded as a first law of our nature.

The doctrine of the vibrations of an ether producing light, and communicating a corresponding vibration to the optic nerve, has had powerful advocates in our day, for explaining the phenomena of vision. But it is quite at variance with anatomy, and assumes more than is usually granted to an hypothesis. It requires us to imagine the existence of an ether; and that this fluid is governed by laws unlike any other fluid of which we have experience. It supposes a nervous fluid and tubes or fibres to exist in the nerve, to receive and convey these vibrations. It supposes everywhere *motion* as the sole means of propagating sensation. The theory has originated in the misconception that, if a certain kind or degree of vibration be communicated to any nerve, this particular motion must be propagated to the sensorium, and a corresponding idea excited in the mind. For example, it is conceived that if the nerve of hearing were placed in the bottom of the eye, it would be impressed with the vibration proper to light, and that this, when conveyed to the brain, would give rise to the sensation of light or colours—all which is contrary to fact. Nor can I be satisfied with the statement that light and colours result

from vibrations which vary "from four hundred "and fifty-eight millions of millions, to seven "hundred and twenty-seven millions of millions "in a second," when I find that a fine needle pricking the retina will produce brilliant light, and that the pressure of the finger on the ball of the eye will give rise to all the colours of the rainbow.

There is a condition of the percipient or sentient principle, residing in the brain and nerves, which conforms, as well as the organ of sense, to the impression to be made, and corresponds with the qualities of matter. The organs of sense may be compared to so many instruments, which the philosopher has recourse to, for distinguishing the several properties of the body which he investigates: as they are not all communicable through any one instrument, he employs different ones; and so in the use of the senses, each organ is provided for receiving a particular impression, and no other.

However mortifying it may be to acknowledge ignorance, a variety in the motion communicated to a body cannot be admitted as the cause of sensation universally. As I said, we are incapable of comprehending anything of the manner in which the nerves are affected. Certainly, we know nothing of the manner in which sensation is propagated or the mind ultimately influenced. There is nevertheless a very pleasing view of the

subject, which is, to observe the correspondence established, through a series of organic parts, between the mind, and the condition or qualities of matter in the external world; for nothing can convey a more sublime idea of Power, and of the unity of the system that includes the organic and inorganic creations.

Returning to the consideration of the sensibility belonging to the skin, or the sense of touch, this property is as distinct an endowment as that which belongs to the eye. It is neither inferior nor more common. It is not consequent upon the mere exposure of the delicate surface of the animal body. It is a distinct sense, the organ of which is seated in the skin; and it is necessary that this organ of sense should be extended widely over the surface of the body. Yet the nerves are as appropriate and distinct, as if they were gathered into one trunk, like those belonging to the organs of vision and hearing. Although the portion of nervous matter on which the sensation of touch depends, be necessarily extended in its sentient extremities over the whole exterior surface of the body, it is very much concentrated towards the brain: and it is there appropriated, in the same manner as the nerves of vision and of hearing, to its peculiar function of raising corresponding perceptions in the mind.

Perhaps this will be better understood from

the fact—that a certain large portion of the skin may be the seat of excruciating pain, and yet the surface, which to the patient's perception is the seat of the pain, will be altogether insensible to cutting, burning, or any mode of destruction! "I have no feeling in all the side "of my face, and it is dead; yet surely it cannot "be dead, since there is a constant pricking "pain in it." Such were the words of a young woman whose disease was at the root of the nerve of sensibility near the brain.* The disease destroyed the function of this nerve of the head, as to its property of conveying sensation from the exterior; and substituted that morbid impression on the trunk of the nerve, which was referred to the tactile extremities.

If we use the term common sensibility, we can do so only in reference to touch: since, from being the most necessary of the senses, it is enjoyed by all animals from the lowest to the highest in the chain of existence. Whilst this sense is distinct from the others, it is the most important of any; for it is through it alone that some animals possess the consciousness of existence; and to those which enjoy many organs of sense, that of touch, as we shall presently show, is necessary to the full developement of the powers, with which they are endowed.

* See papers by the author in the Philosophical Transactions.

OF THE ORGAN OF TOUCH.

Touch is that peculiar sensibility which gives the consciousness of the resistance of external matter, and makes us acquainted with the hardness, smoothness, roughness, size, and form of bodies. It enables us to distinguish what is external from what belongs to us; and while it informs us of the geometrical qualities of bodies, we must refer to this sense also our judgment of distance, of motion, of number, and of time.

Presuming that the sense of touch is exercised by means of a complex apparatus—by a combination of the consciousness of the action of the muscles, with the sensibility of the proper nerves of touch, we shall, in the first place, examine in what respect the organization resembles that of the other senses.

We have said before that, on the most minute examination of the extremities of the nerves expanded on the different organs of sense, no appropriate structure can be detected; and that they appear every where the same,—soft, pulpy, prepared for impression, and so distributed that the impression shall reach them. What is termed the structure of the organ of sense, is that apparatus by which the external impression is conveyed inwards, and by which its force is

concentrated on the extremity of the nerve. The mechanism by which these external organs are suited to their offices, is highly interesting; as it serves to shew, in a way that is level to our comprehension, from its resembling things of human contrivance, the design with which the fabric is constructed. Thus we can understand why the eye is so seated and so formed, as to embrace the greatest possible field of vision; we can estimate the happy effects of the convexity of the transparent cornea, and the influence of the three humours, of various densities, acting like an achromatic telescope; we can admire the precision with which the rays of light are concentrated on the retina, and the beautiful provision for enlarging or diminishing the pencil of light, in proportion to its intensity. But all this explains nothing, in respect to the perception that is excited in the mind by the impulse on the extremity of the nerve.

In like manner, in the complex apparatus of the ear, we see how this organ is formed with reference to a double course of impressions,—as they come through the solids of the body itself, and as they come through the atmosphere; we comprehend how the undulations and vibrations of the air are collected and concentrated; how they are directed, through the intricate passages of the bone, to a fluid in which the nerve of hearing is suspended; and we see how, at last,

that nerve is moved. But we can comprehend nothing more from the study of the external organ of hearing.

The illustration is equally clear in reference to the organ of smelling, or of taste. There is nothing in the nerve itself, either of the nose or of the tongue, which can explain why it is susceptible of the particular impression that it receives. For these reasons, we are prepared to expect very little complexity in the organ of touch, and to believe that the peculiarity of the sense consists more in the property bestowed on the nerve, than in the mechanical adaptation of the exterior organ.

OF THE CUTICLE.

The cuticle or epidermis covers the true skin, excludes the air, limits the perspiration, and in some degree regulates the heat of the body. It is a dead or insensible covering; it guards from contact the true vascular surface of the skin; and in this manner, it often prevents the communication of infection. We are most familiar with it as the scarf skin which scales off after fevers, or by the use of the flesh-brush, or by the friction of the clothes; for it is continually separating in thin scales, whilst it is as regularly formed anew by the vascular surface

below. The condition of this covering is intimately connected with the organ of touch. The habit of considering that certain textures may be produced accidentally, has induced some anatomists to believe that the cuticle is formed by the hardening of the true skin. The fact, however, that the cuticle is perfect in the new-born infant, and that even then it is thickest on the hands and feet, should have shewn that, like every thing in the animal structure, it participates in the great design.

The cuticle is the organ of touch in this respect, that it is the medium through which the external impression is conveyed to the nerves of touch; and the manner in which this is accomplished is not without interest.

The extremities of the fingers exhibit all the provisions for the exercise of this sense. The nails give support to the fingers; they are made broad and shield-like,* in order to sustain the elastic cushion which forms their extremity. This cushion on the end of the finger is a very important part of the exterior apparatus: its fulness and elasticity adapting it admirably for touch. An ingenious gentleman has observed that we cannot feel the pulse at the wrist with the tongue. It is a very remarkable fact; and I apprehend that it is owing, not to the insensi-

* *Unguis scutiformis.*

bility of the tongue, but to the softness of its texture. The tip of the tongue is not fitted to receive the peculiar impulse, to which the firm and elastic pad of the finger is so perfectly suited. Is it not interesting to find that, had the organ of touch been formed as delicately as the tongue, we should positively have lost one of our inlets to the knowledge of matter!

But to return—on a nearer inspection, we discover a more particular provision in the points of the fingers for adapting them to touch. Where-ever the sense of feeling is most exquisite, there we see minute spiral ridges of the cuticle. These ridges have depressed lines corresponding with them on the inner surface of the cuticle; and these again give lodgment to a soft pulpy matter, in which lie the extremities of the sentient nerves. Thus the nerves are adequately protected, while they are at the same time sufficiently exposed to have impressions communicated to them through the elastic cuticle, and thus to give rise to the sense of touch. The organization is simple, yet it is in strict analogy with the other organs of sense.

Every one must have observed a tendency in the cuticle to become thickened and stronger by pressure and friction. If the pressure be partial and severe, the action of the true skin is too much excited, fluid is thrown out, and the cuticle is raised in a blister. If it be still

partial, but more gradually applied, a corn is formed. If, however, the general surface of the palms or soles be exposed to pressure, the cuticle thickens, until it becomes a defence like a glove or a shoe. Now, what is most to be admired in this thickening of the cuticle is, that the sense of touch is not lost, or indeed diminished, certainly not at all in proportion to the increased protection afforded by it to the skin.

The thickened cuticle partakes of the structure of the hoofs of animals. We may therefore attend to the nature of a hoof, for example, that of the horse, as the best possible illustration of the manner in which the sensibility of the skin is in a due degree preserved, whilst the surface is completely guarded against injury.

The human nail is a continuation of the cuticle, and the hoof of an animal belongs to the same class of parts. In observing how the nerves are disposed with regard to the hoof, we have presented to us, in fact, a magnified view of the same structure which exists, only more minutely and delicately, in the cuticular covering of the fingers. The crust or hoof is in itself altogether insensible: but on separating it from the part which it covers, we perceive that its inner surface is marked by numerous pores or fissures. The surface with which the hoof is in contact, on the other hand, possesses, during life,

a high degree of vascularity and sensibility; and we see projecting from it small villi,* containing blood vessels and nerves, that enter into the pores or fissures of the hoof, where they are securely lodged: when we detach the hoof from the vascular and nervous surface, we can see these delicate tufts or villi, as they are pulled out from the spaces which they occupied. These processes from the vascular surface are not merely extremities of nerves; they consist of the nerves with the necessary accompaniment of membrane and blood vessels, on a very minute scale: for it must be remembered that nerves can perform no function unless supplied with blood, all qualities of life being supported through the circulating blood. These nerves, so prolonged within the villi into the hoof, receive the vibrations of that body: and by this means, the horse is sensible to the motion and pressure of its foot, or to its percussion against the ground; without which provision, there would be a certain imperfection in the limb.

In a former part of this treatise, I have shewn by what a curious mechanism the horse's foot is rendered yielding and elastic, so as to enable it to bear the shocks to which it is liable. But owing to our made roads, and the imperfections of shoeing, the pressure and concussion are too

* VILLI, delicate tufts, like the pile of velvet, projecting from the surface of any membrane.

severe and too incessant, not to be attended with injury of the foot; accordingly, inflammation arises; and then the protecting sensibility is converted into a source of pain; the horse is "foundered." There is a remedy for this condition, in dividing the nerve across before it reaches the foot; the consequence of which operation is, that the horse, instead of moving with timid steps, puts out his feet freely, and the lameness is cured. However, if we received the statement thus barely, the fact would militate against our conclusion, that the mechanical provision and the sensibility are equally necessary to the perfection of the instrument, and require to be associated together. It may relieve us from the difficulty, if we take into consideration this leading fact, that pressure against the sole and crust is necessary to the play of the foot and to its perfection: when the foot is inflamed, the animal does not put it freely down; it does not bear its weight upon the hoof so as to bring all the parts into action; hence contraction is produced, the most common defect, as we before said, of the horse's hoof. But when the animal is relieved from its pain by the division of the nerve, it then uses the foot freely, and use restores all the natural actions of this fine piece of mechanism.

It is obvious, however, that when the nerve is cut across, there must be a certain defect; the horse will have lost his natural protection, and

must now be indebted to the care of his rider. He will not only have lost the pain which should guard against over exertion, but the feeling of the ground, which is necessary to his being perfectly safe as a roadster.

The teeth are provided with sensibility, much in the same manner as the hoof of the horse Although the bone and the enamel have no sensibility, yet a branch of a sensible nerve (the fifth) enters into the cavity of every tooth ; and as a vibration can thus be communicated through the tooth to the nerve, the smallest grain may be felt between the teeth.

But, to return to the human hand. If a man uses the forehammer, the cuticle of the fingers and palm will become thickened in a remarkable manner. The depressed lines, however, on its inner surface become also deeper, and the villi projecting into them longer; the consequence of which is, that owing to the aptitude of the cuticle to convey the impressions still to these included nerves, he continues to possess the sense of touch in a very high degree.

In the foot of the ostrich* we may behold a magnified view of the thickened cuticle, disposed like the thickset hairs of a brush, and into which the lengthened nerves are prolonged. This outer skin of the foot is almost equal in thick-

* See engraving, p. 107.

ness to the hoof of the *solidungula.* When separated from the sensible sole, the villi, or papillæ, containing within them the nerves, are withdrawn from each of the processes of cuticle, leaving corresponding foramina or pores. If the object had been merely to cover and protect the foot, it would have been sufficient to have invested the sole with a succession of solid and dead layers of cuticle ; and this would have been the kind of covering that the foot would have received, had the cuticle been merely thickened by pressure; and had there been no design to make a provision adapted in all respects to the habits of the bird.

Such, then, is the structure of the organ of touch: obvious in the extremities of the fingers; magnified in the foot of the horse or of the ostrich ; and existing even in the delicate skin of the lips.

I have casually noticed that increased vascularity always accompanies the distribution of nerves to a part, as being necessary to sensibility. In the museum of the College of Surgeons we see that Mr. Hunter had taken the pains to demonstrate this, by the injection of the blood vessels of a slug. Although fluid was injected from its heart, the blush from the vermilion extends over its foot ; the foot, in these gasteropoda. being the whole lower flat surface on which the animal creeps. This surface is also

the organ of touch, by which it feels and directs its motions. It is on the same principle, if we may compare such things, that we explain the rosy tipped fingers and the ruby lips; the colour implies that the fine sensibility of these parts is combined with high vascularity.

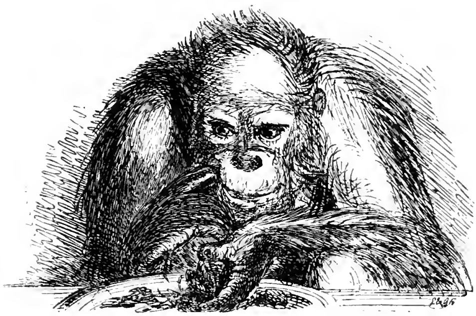
Having described the relation of the cuticle to the nerves of touch, we may take notice of the advantages accruing from another of its qualities, its roughness. In the first place, as to the subserviency of this roughness of the surface to feeling, we must be sensible that when we touch a finely polished surface, the organ is but imperfectly exercised, compared with the effect produced by touching or grasping a rough and irregular body. Had the cuticle been finely polished on its surface, it would have been ill suited to touch: but as it has, on the contrary, a very peculiar roughness, it is admirably adapted to feeling. A provision for increasing friction is especially necessary in some parts of the skin. Thus the roughness of the cuticle in the palm of the hand and the sole of the foot has the advantage of giving us a firmer grasp, and a steadier footing: nothing is so little apt to slip, as the thickened cuticle, either of the hand or foot. In the hoofs of animals, as might be expected, this structure is further developed. It is owing to a quality of this kind that the chamois, ibex, or goat, steps securely on the

narrow ledges of rocks, and at great heights, where it would seem impossible to cling. So in the pads or cushions of the cat, the cuticle is rough and granular; and in the foot of the squirrel, indeed of all animals which climb, we find the pads covered with the cuticle in a similar manner; which allows them to descend the branch securely, while their claws enable them to grasp and cling to it.

In concluding this section, we perceive that the organ of touch consists of nerves, appropriated to receive the impressions of bodies which are capable of offering resistance. Fine filaments of these nerves, wrapt up in delicate membrane, with their accompanying arteries and veins, project from the true skin into corresponding grooves or foramina of the cuticle. These filaments are not absolutely in contact with the cuticle, but are surrounded with a semi-fluid matter. By this fluid and by the cuticle the nerves are protected, at the same time that they are sensible to the pressure made on the surface, and to cutting, pricking, and heat.* But this

* It is a curious confirmation of the fact, that the cutaneous nerve is adapted to receive impressions from the varieties of temperature, that when disease takes place in the centre of the trunk of a nerve, or when the nerve is surrounded with diseased parts, the sensation of burning accompanies the pain; and the patient refers this to the part of the skin to which the extreme branch of the nerve is distributed. By a burning sensation in the sole of the foot, I have been directed to disease seated in the centre of the thigh.

capacity, we repeat, is not owing, strictly speaking, to any thing in the structure of the organ, but to the appropriation of the nerve to this class of sensations.



CHAPTER IX.

OF THE MUSCULAR SENSE.

Of the Sensibility of the Infant to Impressions, and the gradual Improvement of the Sense of Touch.

A NOTION prevails that the young of the lower animals are directed by instinct, but that there is an exception in regard to the human offspring: that in the child we have to trace the gradual dawn and progressive improvement of reason. This is not quite true; we doubt whether the body would ever be exercised under the influence of reason alone, and if it were not first directed by sensibilities which are innate or instinctive.

The sensibilities and the motions of the lips and tongue are perfect from the beginning; and the dread of falling is shewn in the young infant long before it can have had experience of violence of any kind.

The hand, which is to become the instrument for perfecting the other senses and developing the endowments of the mind itself, is in the infant absolutely powerless. Pain is poetically

described as that power into whose "iron grasp" we are consigned, to be introduced to a material world; now, although the infant is capable of an expression of pain, which cannot be misunderstood, and is the same which accompanies all painful impressions during the whole life, yet it is unconscious of the part of the body which suffers. We have again recourse to the surgeon's experience. There occur certain congenital imperfections which require an operation at this early stage of life; but the infant makes no direct effort with its hand to repel the instrument, or to disturb the dressing, as it will at a period somewhat later.

The lips and tongue are first exercised; the next motion is to put the hand to the mouth, in order to suck it: and no sooner are the fingers capable of grasping, than whatever they hold is carried to the mouth. So that the sensibility to touch in the lips and tongue, and their motions, are the first inlets to knowledge; and the use of the hand is a later acquirement.

The knowledge of external bodies as distinguished from ourselves, cannot be acquired until the organs of touch in the hand have become familiar with our own limbs; we cannot be supposed capable of exploring any thing by the motion of the hand, or of judging of the form or tangible qualities of an object pressed against the skin, before we have a knowledge of our

own body as distinguished from things external to us.

The first office of the hand, then, is to exercise the sensibility of the mouth: and the infant as certainly questions the reality of things by that test, as the dog does by its acute sense of smelling. In the infant, the sense of the lips and tongue is resigned in favour of the sense of vision, only when that sense has improved and offers a greater gratification, and a better means of judging of the qualities of bodies. The hand very slowly acquires the sense of touch, and many ineffectual efforts may be observed in the arms and fingers of the child, before the direction of objects or their distance is ascertained. Gradually the length of the arm, and the extent of its motions become the measure of distance, of form, of relation, and perhaps of time.

Next in importance to the sensibility of the mouth, we may contemplate that sense which is early exhibited in the infant,—the terror of falling. The nurse will tell us that the infant lies composed while she carries it in her arms up stairs; but that it is agitated in carrying it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest, whilst it is raised; but they will struggle and make an effort, as it descends. There is here the indication of a sense, an innate feeling of danger, the influence of which

we may perceive, when the child first attempts to stand or run. When the child is set upon its feet, and the nurse's arms form a hoop around it without touching it, it slowly learns to balance itself and stand; but under a considerable apprehension. Presently, it will stand at such a distance from the nurse's knee, that if it should lose its balance, it can throw itself for protection into her lap. In these its first attempts to use its muscular frame, it is directed by an apprehension which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children, therefore, are cowardly by instinct: they show an apprehension of falling; and we may gradually trace the efforts which they make, under the guidance of this sensibility, to perfect the muscular sense. In the mean time, we perceive how instinct and reason are combined in early infancy: how necessary the first is to existence: how it is subservient to reason: and how it yields to the progress of reason, until it becomes so obscured that we can hardly discern its influence.

When treating of the senses, and showing how one organ profits by the exercise of the other, and how each is indebted to that of touch, I was led to observe that the sensibility of the skin is the most dependant of all on the exercise of

another quality. Without a sense of muscular action or a consciousness of the degree of effort made, the proper sense of touch could hardly be an inlet to knowledge at all. I have now to show that the motion of the hand and fingers, and the sense or consciousness of the action of the muscles in producing these motions, must be combined with the sense of touch, properly so called, before we can ascribe to this sense the influence which it possesses over the other organs.

In my general course of lectures on anatomy, I ventured on this explanation from the commencement; much doubting, however, the correctness of my reasoning, when I saw that the great authorities on this subject, when treating of the senses, made no account of the knowledge which is derived from the motions of our own frame. I called this consciousness of muscular exertion a sixth sense; considering it to be essential to the exercise of the sense of touch. I can now refer, in confirmation of this view, to the works of philosophers who have been educated to medicine; and to whom the necessity of the combination of the two faculties had suggested itself as it had to me.* Those distinctions were connected with my enquiries into the functions of the nervous system, and in some measure directed them.†

* See Dr. Brown's Lectures on Moral Philosophy.

† It was this conviction—that we are sensible of the action of the muscles, which led me to the investigation of their nerves;

The Abbé Nollet, after extolling the sense of touch as superior to all the other senses, and as deserving to be considered the *genus* under which the others should be included as subordinate *species*, makes this remark—" Besides, it " has this advantage over them, to be at the " same time both active and passive: for it not " only puts it in our power to judge of what " makes an impression upon us, but likewise of

first, by anatomy, and then by experiment. I was finally enabled to show that the muscles had two classes of nerves—that on exciting one of these, the muscle contracted: that on exciting the other, no action took place. The nerve which had no power to make the muscle contract was found to be a nerve of sensation. Thus, it was proved that there is a nervous circle connecting the muscles with the brain: that one nerve is not capable of transmitting what is called the nervous spirits, in two different directions at one instant of time; but that for the regulation of muscular action, there is a nerve of sensibility to convey a sensation of the condition of the muscles to the sensorium, as well as a nerve of motion for conveying the mandate of the will to the muscles. In their distribution through the body, the nerves which possess these two distinct powers, of conveying sensation and of exciting the muscles to contraction, are wrapped up, or, as it were, woven together in the same sheath; and they present to the eye the appearance of one nerve. It was only by examining the nerves at their roots, that is, where they arise from different tracts of the brain and spinal marrow, and before they have coalesced, that I succeeded in demonstrating their distinct functions. In the face, the nerve of motion passes by a circuitous course, apart from the nerve of sensation, to be distributed to the muscles; and therefore the distinct characters of these two nerves were more easily proved by experiment than in any other part of the body. See the Philosophical Transactions on the " Nervous Circle which connects the Voluntary Muscles with the Brain," and the " Nervous System." Third edition, 1836.

"what resists our impulsions." The mistake here lies in giving to the nerves of touch a property which must belong to the actions of muscles. So it is affirmed by physiologists, as I have already had occasion to state, that the sense of touch differs from the other senses by this circumstance—that an effort is propagated towards it, as well as a sensation received from it. This confusion obviously arises from considering the muscular agency, which is directed by the will during the exercise of touch, as belonging to the nerve of touch properly. I proceed to show how the sense of motion and that of touch are necessarily combined.

When a blind man, or a man with his eyes shut, stands upright, neither leaning upon, nor touching aught; by what means is it that he maintains the erect position? The symmetry of his body is not the cause. The statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the winds that blow upon him? It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense then is this? for he touches nothing, and sees nothing; there is no organ of sense hitherto observed

which can serve him, or in any degree aid him. Is it not that sense which is exhibited so early in the infant, in the fear of falling? Is it not the full developement of that property which was early shown in the struggle of the infant, while it yet lay in the nurse's arms? It can only be by the adjustment of muscles, that the limbs are stiffened, the body firmly balanced, and kept erect. There is no other source of knowledge but the sense of the degree of exertion in his muscular frame, by which a man can become conscious of the position of his body and limbs, while he has no point of vision, or the contact of any external body to direct his efforts. In truth, we stand by so fine an exercise of this power, and the muscles are, from habit, directed with so much precision, and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or stand in a situation where we are in danger of falling, or rest on one foot, we become then subject to apprehension: the actions of the muscles are, as it were, magnified, and demonstrative of the degree in which they are excited.

We are sensible of the position of our limbs; we know that the arms hang by the sides; or that they are raised and held out; although we touch nothing and see nothing. It must be a property internal to the frame by which we can thus learn the position of the members of our

body: and what else can it be but a consciousness of the degree of action, and of the adjustment, of the muscles? At one time, I entertained a doubt whether this proceeded from a knowledge of the condition of the muscles, or from a consciousness of the degree of effort which was directed to them in volition. It was with a view to elucidate this, that I made the observations which terminated in the discovery that every muscle had two nerves—one for sensation, and one for conveying the mandate of the will and directing its action. I had reasoned in this manner—we awake with a knowledge of the position of our limbs: this cannot be from a recollection of the action which placed them where they are; it must, therefore, be a consciousness of their present condition. When a person in these circumstances moves, he has a determined object; and he must be conscious of a previous condition before he can desire a change or direct a movement.

After a limb has been removed by the surgeon, the person still feels pain, and heat, and cold in it. Urging a patient to move who has lost his limb, I have seen him catch at the limb to guard it, forgetful that it was removed; and long after his loss, he experiences a sensation not only as if the limb remained, but as if it were placed or hanging in a particular position or posture. I have asked a patient—" Where do

" you feel your arm now?" and he has said, " I " feel it as if it lay across my breast," or that it is " lying by my side." It seems also to change with the change of posture of the body. These are additional proofs of a muscular sense; that there is an internal sensibility corresponding with the changing condition of the muscles; and that as the sensations of an organ of sense remain, after the destruction of the outward organ, so a deceptious sensibility to the condition of the muscles, as well as to the condition of the skin, will be felt after the removal of the limb.

By such arguments I have been in the habit of showing that we possess a muscular sense, and that without it we could have no guidance of the frame. We could not command our muscles in standing, far less in walking, leaping, or running, had we not a perception of the condition of the muscles previous to the exercise of the will. And as for the hand, it is not more the freedom of its action which constitutes its perfection, than the knowledge which we have of these motions, and our consequent ability to direct it with the utmost precision.

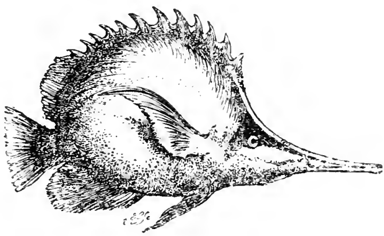
The necessity for the combination of two distinct properties of the nervous system in the sense of touch becomes more obvious, if we examine their operation in other but analogous organs; for example, in the palpa or tentacula of the

lower animals. These animals use the instruments that are so called for groping their way: and they consist of a rigid tube containing a pulpy matter, in which there is a branch of a nerve that possesses, in an exquisite degree, the sense of touch. Now when this instrument touches a body and the vibration runs along the pulp of the nerve, the animal can be sensible only of an obstruction: but where is that obstruction, and how is the creature's progress to be directed to avoid it? We must acknowledge, when we see the instrument moving about and feeling on all sides, that it is the action of the muscles communicating this motion to it, and the sense of their activity, which convey the knowledge of the place or direction of the obstructing body. It appears, therefore, that even in the very lowest creatures, the sense of touch implies the comparison of two distinct senses.

That insects have the most exquisite organs of sense must be allowed: but we do not reflect on the extraordinary accuracy with which they measure distances in their movements. This they can only do through an adaptation of the muscular exertion to the sense of vision. The spider to which I have already alluded in a former chapter —the *aranea scenica*, when about to leap, elevates itself upon its fore legs, and lifting its head, seems to survey the spot before it jumps; if it spies a small gnat or fly upon the wall, it creeps very

gently towards it, with short steps, till it comes within a proper distance, and then it springs suddenly upon it like a tiger. It will jump two feet to seize upon a bee.*

We have a more curious instance of the precision of the eye and of the adaptation of muscular action, in the *chœtodon rostratus.*† This fish inhabits the Indian rivers, and lives on the



smaller aquatic flies. If it observe one of these insects, alighted on a twig, or flying near (for it can shoot them on the wing), it darts forth a drop of water from its beak, with so steady an aim as to bring the fly into the water, when it falls an easy prey. These fishes are kept in large vases for amusement, and if a fly be presented on the end of a twig, they will shoot at it with surprising accuracy. In its natural state it will hit a fly at the distance of from three to six feet. The *zeus insidiator*‡ has also the same power of forming its mouth into a tube, and

* Kirby.

† Chœtodon, a genus of the Acanthopterygii.

‡ Belonging to another genus of the same Order.

squirting at flies, so as to encumber their wings and bring them to the surface of the water. Whether we are led, by such instances, to admire the wonderful power of instinct in these inferior creatures; or to examine the property acquired by ourselves, we must acknowledge a compound operation to be necessary for explaining the effects.*

The impression of odours on the nerve of smelling, some would have us believe, is exactly similar to the effect of light on the nerve of vision; and yet it is supposed that the impression on the nerve of vision alone suffices to inform us of every thing that we know through the eye. Now of the direction and distance from which odours come, we are quite ignorant, until we make a comparison, by turning the head and directing the nostrils, and moving this way and that; and at length we discover on which side the smell is strongest on the sense.

In insects, the motion of the body is rendered subservient to smelling, as well as to vision. There is nothing in the mere exercise of the organ of smelling, that can direct it in its flight. Yet if a piece of carrion be thrown out, the flies will approach it,—not in a direct line, but by

* In these instances a difficulty will readily occur to the reader; how does the fish judge of position, since the rays of light are refracted at the surface of the water? Does instinct enable it to do this, or is it by experience?

coming towards it in circles. So it is with the bees, in a garden, when attracted to a flower: they may be seen, at first, flying wide, describing circles in their flight, each circle diminishing as they come nearer, until they at last alight upon the object. Having no organ by which they can inhale the effluvia, they make currents in the air by their mode of flight, so as to impress the nerve of smelling: and it is from the sense of the odour being more acute in one part of the circle, that the next wheel is made; and thus they are directed to the flower, as it were in a line drawn through these circles.

We can judge of the direction from which sounds proceed, without its being necessary to turn the head towards them; because the strength of the vibration is unequal on the two sides of the head, and we can therefore readily form a comparison between the two impressions. But when a person is deaf in one ear, the operation is difficult; he is often mistaken as to the direction of the sounds, and has more frequent occasion to turn the head and to compare the position of the tube of the ear with the strength of the impressions. Accordingly, in mixed company, where there are many speakers, a man in this condition appears positively deaf, from the impossibility of his distinguishing minutely the direction of sounds.

The last proof of the necessity of the combina-

tion of the muscular sense with the sense of contact will be conclusive. The following is not a solitary instance:—

A mother while nursing her infant was seized with a paralysis, attended by the loss of power on one side of her body and the loss of sensibility on the other side. The surprising, and, indeed, the alarming circumstance here was, that she could hold her child to her bosom with the arm which retained muscular power, but only as long as she looked to the infant. If surrounding objects withdrew her attention from the state of her arm, the flexor muscles gradually relaxed, and the child was in danger of falling. The details of the case do not belong to our present enquiry; but we see, first, that two distinct properties are possessed by the arm, which is evinced by the loss of the one, and the continuance of the other; secondly, that these two properties exist through different conditions of the nervous system; and, thirdly, we perceive how ineffectual the muscular power is, for the exercise of the limbs, without the sensibility which should accompany and direct it.

The capacity, therefore, which the hand enjoys of ascertaining the distance, the size, the weight, the form, the hardness or softness, the roughness or smoothness of objects, results from its having a compound function—from the sensibility of the proper organ of touch, being combined with the

consciousness of the motion of the arm, hand, and fingers.

But it is the motion of the fingers that is especially necessary to the sense of touch. These bend, or extend, or expand, or move in every direction, like palpa, with the advantage of embracing the object, feeling it on all its surfaces, estimating its solidity or its resistance when grasped, moving round it, and gliding over its surfaces, so as to feel every asperity, and be sensible of every slight vibration.

THE PLEASURES ARISING FROM THE MUSCULAR SENSE.

The exercise of the muscular frame is the source of much of the knowledge usually supposed to be obtained through the organs of the senses; and to this source, also, we may trace some of our chief enjoyments. We may, indeed, affirm that it is the benevolent intention of nature that the vigorous circulation of the blood, and, therefore, the healthful condition both of the mind and of the body, shall result from muscular exertion, and the alternations of activity and repose.

The pleasure which proceeds from the activity of the body, may be, in part, due to the gratification that naturally arises from the exercise of any kind of power—as the power implied by dexterity, merely; or that implied by success-

ful pursuit in the field, or by the accomplishment of some work of art. But independently of this, active exercise is followed by weariness, and a desire for rest. Now, although this condition is unattended with any describable pleasure or local sensation, there is diffused, through every part of the frame, after fatigue, and whilst the active powers are sinking into repose, a feeling almost voluptuous. To this feeling the impatience of rest succeeds; and thus we are urged to follow the alternations of activity and repose necessary to health; and are invited on, from stage to stage of our existence.

We owe other enjoyments to the muscular sense. It would appear that, in modern times, comparatively little is thought of the pleasures arising from motion: yet the gravest of the Greeks, and even of the Romans, we know, studied elegance in their attitudes and their movements. Their apparel was more favourable for this display: and their exercises and games must have contributed to encourage this care. But the dances which they performed, were not to exhibit mere exuberance of spirits and activity; they combined harmony in the motion of the body and limbs, with majesty of gait, and consisted more of the unfolding of the arms, than of the play of the feet,—"Their arms sublime, that floated on the air." The Pyrrhic dances were elegant movements, joined to the attitudes

of combat, and performed in correct coincidence with the expression of the music. The spectators in their theatres must have had very different associations from ours, to account for the national enthusiasm displayed by the influence of the music, and their rage excited by a mere error in the time.

This may remind us that the divisions of the time, in music, in some degree depend on the muscular sense. A man will put down his staff in regulated time, and in his common walk, the sound of his steps will fall into a measure. A boy striking the railing in mere wantonness, will do it with a regular succession of blows. This disposition in the muscular frame to put itself into motion with an accordance to time, is the source of much that is pleasing in music, and assists the effect of melody. The closest connection is thus established between the enjoyments of the sense of hearing and the exercise of the muscular sense.*

The effect of disorders of the nervous system is sometimes to show, how natural certain combina-

* It is probable that we must ascribe to this, the power which music possesses over the passions, and even over disease. It is recorded that the music master of Socrates [and many will be pleased to know that so wise a man had a music master] seeing one inflamed with wine, and intent on burning the house, whilst the flute was played in Phrygian measure, cured him by ordering the tibicina [a female flute player] to change her mode to the measure given to the *spondee*, a grave and soothing style! Galen

tions of actions are, in the exercise of the muscular frame. The following is a curious illustration of what we have just been dwelling upon. A young woman, who, by the bye, could not be taught to go down a country dance, under a morbid mental excitement, in association with the organs of voluntary motion, began to execute involuntary movements, not unbecoming an opera dancer. At one time, she would pace slowly round the room, as in a minuet, with a measured step, the arms carried with elegance; at another time, she would stand on the toes of one foot, and beat time with the other. On some occasions she would strike the table, or whatever she could reach, with her hand, many times softly, and then with force. At length it was found that she did every thing in rhythm. A friend thought that, in her regular beating, he could recognise a tune, and he began singing it. The moment this struck her ears, she turned suddenly to the man, danced directly up to him, and continued to dance, until he was quite out of breath.

The cure of this young woman was of a very unusual kind: a drum and fife were procured,—

records instances of the influence of music over the passions and over disease. And it appears to have been resorted to by Egyptians, Hebrews, Greeks, and Romans, both in acute and chronic diseases.

To learn how much of the enjoyment of the sense of vision depends on muscular action, see the "Additional Illustrations," at the end of the volume.

and when a tune, corresponding to the rhythm of her movements was played, in whatever part of the room she was, she would dance close up to the drum, and continue dancing until she missed the step; when these involuntary motions instantly ceased, and the paroxysm ended. The physician profiting by this, and observing a motion in her lips, put his ear close to her mouth; he thought he could hear her sing; and questioning her, she said that there always was a tune dwelling upon her mind, which at times had an irresistible influence upon her, and impelled her to begin her involuntary motions. In the end, she was cured by altering the time in the beating of the drum; for whenever she missed the time, the motions stopped.*

We may now ask, what is this extraordinary disease? From being an excitable state of the nervous and muscular system, it will be called *Chorea:* but it is an instance of a natural combination of muscular actions, morbidly produced; just as in hysteria, where we have the expression of various natural passions exhibited, for example, weeping or laughing.

* Med. Chir. Trans. vol. vii.

CHAPTER X.

THE HAND NOT THE SOURCE OF INGENUITY OR CONTRIVANCE, NOR CONSEQUENTLY OF MAN'S SUPERIORITY.

Seeing how perfect both the structure and endowments of the hand are, we can hardly be surprised that some philosophers should have entertained the opinion of Anaxagoras, that the superiority of man was owing to his hand. The system of bones, muscles, and nerves, which be-

longs to this extremity, is suited to every form and condition of vertebrated animals; yet we must confess that it is in the human hand, that we perceive the consummation of all perfection as an instrument. This superiority consists in its power, which is a combination of strength, with variety, extent, and rapidity, of motion; in the forms, relations, and sensibility of the fingers and of the thumb; in the provisions for holding, pulling, spinning, weaving, and constructing; properties which may be found in other animals, but are combined in this more perfect instrument.

By possessing these provisions, the hand corresponds with the superior mental capacities with which man is endowed: the instrument being capable of executing whatever his ingenuity suggests. Nevertheless, the possession of the ready instrument is not the cause of man's superiority; nor is its aptness for execution the measure of his attainments. So, we rather say with Galen, that man has hands given to him, because he is the wisest of creatures, than ascribe his superiority and knowledge to the use of his hands.*

* Ita quidem sapientissimum animalium est homo: ita autem et manus sunt organa sapienti animali convenientia. Non enim quia manus habuit propterea est sapientissimum, ut Anaxagoras dicebat: sed quia sapientissimum erat, propter hoc manus habuit, ut rectissime censuit Aristoteles. Non enim manus ipsæ homines artes docuerunt, sed ratio. Manus autem ipsæ sunt artium organa: sicut lyra, musici, et forceps, fabri.

This question has arisen from observing the perfect correspondence between the propensities of animals and their forms and outward organization. When we see a heron standing by the water side, still as a grey stone, and hardly distinguishable from it, we may ascribe this habit to the acquired use of its feet, constructed for wading, and to its long bill and flexible neck; for the neck and bill are as much suited to its mode of seizing its prey, as the liester is to the fisherman. But there is nothing in the configuration of the black-bear, particularly adapted for his catching fish; yet he will sit, on his hinder extremities, by the side of a stream, morning or evening, on the watch, like a practised fisher, and so perfectly motionless as to deceive the eye of the Indian, who mistakes him for the burnt trunk of a tree; when he sees his opportunity favourable, he will thrust out his fore-paw, and seize a fish with incredible celerity. The exterior organ is not, in this instance, the cause of the habit or of the propensity; and if we thus see the instinct bestowed without the appropriate organ, may we not the more readily believe, in other examples, when the two are conjoined, that the habit exists with the instrument, although not through it?

The canine teeth are not given without the carnivorous appetite; nor is the necessity of living by carnage joined to a timid disposition;

but boldness and fierceness, as well as cunning, belong to the animal which has retractile claws and sharp teeth, and which preys on living animals.* On the other hand, the propensities of the timid vegetable feeder are not to be attributed to his having erect ears and prominent eyes: though his suspiciousness and timidity correspond with them. The boldness of the bison and buffalo may be as great as that of the lion; but the impulse that directs them in their mode of attack is different: they are guided by instinct to gore with their horns; and they will so strike with their heads whether they have horns or not. "The young calf will butt against "you before he has horns," says Galen. The Scotch song has it, "the putting cow is ay a "doddy," that is, the humble cow (*inermis*), although wanting horns, is always the most mischievous. When that noble animal, the Brahmin bull, of the Zoological Gardens, first put his hoof on the sod and smelt the fresh grass after his voyage,—placid and easily managed before, he became excited, plunged, and struck his horns into the earth, and ploughed up the ground on alternate sides, with a very remarkable precision. This was his dangerous play; just as the

* In some of the quadrumana, the canine teeth are as long and sharp as those of the tiger—but in them they are only instruments of defence, and have no relation to the appetite, or mode of digestion, or internal organization.

dog, in his gambols, worries and fights: or the cat, though pleased, puts out its claws. It would, indeed, be strange, where all else is perfect, if the instinctive character or disposition of the animal were at variance with its arms or instruments.

But the idea may still be entertained that the accidental use of the organ may conduce to its more frequent exercise, and to the production of a corresponding disposition. Such an hypothesis would not explain the facts. The late Sir Joseph Banks, in his evening conversations, told us that he had seen, what many perhaps have seen, a chicken catch at a fly whilst the shell stuck to its tail. Sir Humphrey Davy relates that a friend of his, having discovered under the burning sand of Ceylon the eggs of an alligator, had the curiosity to break one of them; when a young alligator came forth, perfect in its motions and in its passions; for although hatched under the influence of the sunbeams, in the sand, it made towards the water, its proper element: when hindered, it assumed a threatening aspect and bit the stick presented to it. We may therefore conclude, that as animals have propensities implanted in them to perform certain motions, to which their external organs are subservient, so their passions or dispositions are given as the means of directing them how to defend themselves or obtain their food.

But this has been well said seventeen hundred years ago. "Take," says Galen, "three "eggs, one of an eagle, another of a goose, and "a third of a viper; and place them favourably "for hatching. When the shells are broken, the "eaglet and the gosling will attempt to fly; "while the young of the viper will coil and twist "along the ground. If the experiment be pro-"tracted to a later period, the eagle will soar "to the highest regions of the air, the goose "betake itself to the marshy pool, and the viper "will bury itself in the ground."

We have daily before us the proofs of ingenuity in the arts, not only surviving the loss of the hand; but excited and exercised where the hands were wanting from birth. What is more surprising than to see the feet, in individuals under such circumstances, becoming substitutes for the hands, and working minute and curious things? Unfortunately too, the most diabolical passions, in some natures, will be developed, and crimes committed where we might have supposed them impossible, from the power of execution being denied. The most remarkable instance of this was in a man, who from birth had no arms, like the unfortunate youth described in the early part of the volume. As if possessed by a devil, this wretch had committed many murders, before he was discovered and executed. He was a beggar, who took his stand on the high way some miles

from Moscow, on the skirts of a wood: and his manner was, to throw his head against the stomach of the person who was in the act of giving him charity, and having stunned him, to seize him with his teeth and so drag him into the wood!

But to turn to a more agreeable part of our subject. The possession of an instrument like the hand, implies that there must be a great part of the organization which strictly belongs to it, concealed. The hand is not a thing appended, or put on, to the body, like an additional movement in a watch; but a thousand intricate relations must be established throughout the whole frame in connection with it: not only must appropriate nerves of motion and nerves of sensation be supplied, and an original part in the composition of the brain, which shall have relation to them; but even with all this superadded organization, the hand would lie inactive, unless a propensity were created to put it into operation.

Voltaire has said that Newton, with all his science, knew not how his arm moved. So true it is that all such studies have their limits! But, as he acknowledges, there is a wide difference between the ignorance of the child or of the peasant, and the consciousness of the philosopher, that he has arrived at a point beyond which man's faculties do not carry him.

We may ask, is it nothing to have our minds

awakened to the perception of the numerous proofs of design, that present themselves in the study of the hand—to be brought to the conviction that every thing is orderly and systematic in its structure,—that the most perfect mechanism, the most minute and curious apparatus, and sensibilities the most delicate and appropriate, are all combined in operation, that we may move the hand? What the first impulse to motion is, we do not know, nor how the mind is related to the body; yet it is important to learn with what extraordinary contrivance, and with what a perfection of workmanship, the bodily apparatus is placed between that internal faculty, which impels us to use it, and the exterior world.

I have been asked by men of the first education and talents, whether any thing really deficient had been discovered in the organs of voice of the oran-outang, to prevent him from speaking? The reader will give me leave to place this matter correctly before him. In speaking, there is first required a certain force of expired air, or an action of the whole muscles of respiration; in the second place, the vocal chords, at the top of the wind-pipe, must be drawn into accordance by their muscles, else no vibration will take place, and no sound issue; thirdly, the open passages of the throat must be expanded, contracted, or extended, by their numerous mus-

cles, in correspondence with the condition of the vocal chords or glottis ; and these must all sympathize, before even a simple sound will be produced. But to articulate that sound, so that it may become a part of a conventional language, there must be added an action of the pharynx, of the palate, of the tongue and lips. The exquisite organization for all this, is not visible in the organs of the voice, as they are called : it is to be found in the nerves, which combine these various parts in one simultaneous act. The meshes of a spider's web, or the cordage of a man-of-war, are few and simple, compared with the concealed filaments of nerves which move these parts ; and if but one of these nerves be wanting, or its tone or action disturbed in the slightest degree, every body knows how a man will stand with his mouth open, twisting his tongue and lips in vain attempts to utter a word.

It will now appear that there must be distinct lines of association suited to the organs of voice : different to combine them in the bark of a dog, in the neighing of a horse, or in the shrill whistle of the ape. That there are wide distinctions in the structure of the different classes of animals is most certain ; but independently of those which are apparent, there are secret and minute varieties in the associating cords. The ape, therefore, does not articulate—First, because the organs are not perfect to this end.

Secondly, because the nerves do not associate these organs in that variety of action which is necessary to speech. And, lastly, were all the exterior apparatus perfect, there is no impulse to the act of speaking.

Now I hope it appears, from this enumeration of parts, that the main difference lies in the internal faculty or propensity. As soon as a child can distinguish and admire, then are its features in action; its voice begins to be modified into a variety of sounds; these are taken up and repeated by the nurse, and already a sort of convention is established between them. The perfect correspondence between the instrument and the laws governing the motions of the air, is a contrivance; but the source of the articulation, that which prompts to the first efforts, is in our intellectual nature. We cannot, therefore, doubt that a propensity is created in correspondence with the outward organs; and without which, these outward organs would be useless appendages. The aptness of the instrument and its exercise will undoubtedly improve the faculty —just as we find that giving freedom to the expression of passion, adds force to the emotion in the mind.*

* One cannot but reflect here on that grand revolution which took place, when language, till then limited to its proper organ, had its representation in the work of the hand. Now that a man, of mean estate, may have a library of more intrinsic value than

On this, as upon many other occasions, it may be urged that a further multiplication of proofs in favour of natural religion is unnecessary. It may be said that we vary the instances, without making the proofs stronger. For example, no higher argument can be sought for, to prove the perfection of design, than the simple fact, that two intellectual beings, by means of the voice, can breathe out their thoughts, and hold communion on the subject of the ideas that arise in their minds: and the knowledge of the intricate organs by which the voice is produced, can add nothing to our wonder, or to the force of our conviction, that all which regards man's state is ordered in perfection. So, if philosophically considered, it may excite as high admiration, to observe that we can raise the arm by willing it, as when we know all the relations of the nerves and muscles, and bones and joints of the arm, through which the motion is accomplished. But I would ask, who thinks of these proofs of de-

that of Cicero; when the sentiments of past ages may be as familiar to him as those of the present; and when the knowledge of different empires is transmitted and common to all, we cannot expect our sages to be followed, as of old, by their five thousand scholars. Nations will not now record their acts, by building pyramids, or by consecrating temples, and raising statues, once the only means of perpetuating great deeds or extraordinary virtues. It is in vain that our artists complain of patronage being withheld. The ingenuity of the hand has at length subdued the arts of design. Printing has made all other records barbarous; and great men build for themselves a "livelong monument."

sign, or who feels this emotion, while he speaks, or moves his hand? Do these actions excite either admiration or gratitude? Do we not require to be brought to consider them anew, before such feelings arise? Is it not agreeable to know how these actions are performed; and is it not important therefore that the emotions of surprise and gratitude excited by contemplating them, should be repeated and enforced, until they become an enduring devotional feeling? In fine, whilst it is pleasing to reflect that the great authorities in natural science, in times past, have entertained the belief of the great Architect, and of the continuance of his government, it cannot be without its use to add strength to the same belief, by having recourse to the improvements that are daily making in all departments of knowledge.

We must not omit to speak of the hand as an instrument of expression. Formal dissertations have been written on this topic: but were we constrained to seek authorities, we should take the great painters in evidence; since by the position of the hands, in conformity with the figure, they have shown how to express every sentiment. Who, for example, can deny the eloquence of the hands in the Magdalens of Guido: their expression in the cartoons of Raphael: or in the Last Supper, by Leonardo da Vinci? We see in these great works, all that

Quintilian says the hand is capable of expressing.—"For other parts of the body assist the speaker, but these, I may say, speak themselves. By them we ask, we promise, we invoke, we dismiss, we threaten, we intreat, we deprecate, we express fear, joy, grief, our doubts, our assent, our penitence: we show moderation, profusion, we mark number and time."*

Buffon has attempted to convey to us the mode in which knowledge may have been originally acquired, by watching, in fancy, the newly awakened senses of the first created Man. But, for what is both consistent and splendid, in our great Poet, who makes Man raise his wondering eyes to Heaven, and spring up by quick instinctive motion, as "thitherward endeavouring," Buffon substitutes a bad combination of philosophy and eloquence.

To place the subject more distinctly before us, the first created man is made to speak for himself; and the sentence which he utters is to the effect,—"that he remembers the moment of his creation—that time, so full of joy and trouble, when he first looked round on the verdant lawns

* "Nam ceteræ partes loquentem adjuvant, hæ, prope est ut "dicam, ipsæ loquuntur. His poscimur, pollicemur, vocamus, "dimittimus, minamur, supplicamus, abominamur, timemus; "gaudium, tristitiam, dubitationem, confessionem, penitentiam, "modum, copiam, numerum, tempus, ostendimus. &c."

and crystal fountains, and saw the vault of Heaven over his head;" he proceeds then to declare,—" that he knew not what he was or whence he came, and believed that all he saw was part of himself." He is thus represented as conscious of objects, which even to see implies experience, and to enjoy supposes a thousand agreeable associations already formed: but from this blissful state he is awakened—by striking his head against a palm tree, which he had not yet learned could hurt him!

Men are often diffident of their first notions, and conceive that philosophy must lead to something very different from what they have been early taught. Hence perhaps the absurdity of this attempt to unite philosophy and poetry.

Later writers have argued that we have no right to suppose that there has been, at any time, an interruption to the uniform course of nature; meaning by the term, uniformity of nature, the prevalence of the same laws which are now in operation. If it were found, they say, that on the arrival of a colony in a new country, fruits were produced spontaneously around them, and flowers sprung up under their feet, then, we might suppose that our first parents were placed in a scene of profusion and beauty—suited to their helpless condition—and unlike what we see now in the course of nature. It is not very wise to entertain the subject at all; but if it is to

be argued, this is starting altogether wide of the question. We do not desire to know how a whole tribe migrating westward, could find sustenance, —but in what state man could be created and live, without a deviation from what is called the uniform course of nature. If he had been formed helpless as an infant, he must have perished: and if mature in body, he must have been gifted with faculties suited to his condition. A human being, pure from the Maker's hands, with desires and passions implanted in him, adapted to his state, and with a suitable theatre of existence, implies something very near what we have been early taught to believe.

In every change which the globe has undergone, an established relation is perceived between the animal that has been created, and the elements around it. It is idle to suppose that this has been a matter of chance. Either the structure and functions of the animal must have been formed to correspond with the condition of the elements, or the elements must have been controlled to minister to the necessities of the animal; and if the most careful investigation lead us to this conclusion, in contemplating all the inferior gradations of animal existence, what makes us so unwilling to admit such an influence in the last grand work of creation?

We cannot resist these proofs of a beginning, or of design prevailing every where, or of a First

Cause. When we are bold enough to extend our enquiries into the great revolutions that have taken place, whether in the condition of the earth, or in the structure of the animals which have inhabited it, our notions of the "uniformity" of the course of nature must suffer some modification. Changes must, at certain epochs, have been wrought, and new beings brought into existence, differing from those previously existing, or now existing. Such interference is not contrary to the great scheme of creation. It is not contrary to that scheme, but only to our present state. For the most wise and benevolent purposes, a conviction is implanted in our nature that we may rely on the course of events being permanent. We belong to a certain epoch; and it is when our ambitious thoughts carry us beyond our natural condition, that we feel how much our faculties are confined, and our conceptions, as well as our language, imperfect. We must either abandon these speculations altogether, or cease to argue purely from our present situation.

It has now been made manifest, that man and the animals inhabiting the earth have been created with reference to the magnitude of the globe;—that their living endowments bear a relation to their state of existence and to the elements around them; we have also learnt that the system of animal bodies, notwithstanding the

amazing diversity of forms that meet the eye—is simple and universal, and that it not only embraces all living creatures, but has been continued from periods of great antiquity, before the last revolutions of the earth's surface had been accomplished. The most obvious appearances, and the labours of the geologist, give us reason to believe that the earth has not always been in the state in which it is now presented to us: every substance that we see is compound; we nowhere obtain the elements of things: the most solid materials of the globe are formed of decompounded and reunited parts: changes, therefore, have been wrought on the general surface, and the proofs of these are as distinct, as the furrows on a field are indicative that the plough has passed over it. The deeper parts of the crust of the earth, and the animal remains imbedded there, also demonstrate that in the course of these revolutions, long periods or epochs have elapsed between them. In short, progressive changes, from the lowest to the highest state of organization and of enjoyment, point to the great truth, that there was a beginning.

When the geologist sees a succession of stratified rocks—the lowest simple, or perhaps chemical; the strata above these, compound; and others more conglomerated, or more distinctly composed of the fragments of the former—it is not easy to contradict the hypothesis of an eter-

nal succession of causes. But there is nothing like this in the animal body; the material is the same in all, the general design too is the same: but each family, as it is created, is submitted to such new and fundamental arrangements in its construction as implies the presence of the hand of the Creator.

There is nothing in the inspection of the species of animals, which countenances the notion of a return of the world to any former condition. When we acknowledge that animals have been created in succession and with an increasing complexity of parts, we are not to be understood as admitting that there is here proof of a growing maturity of power, or an increasing effort in the Creator: and for this very plain reason, which we have stated before, that the bestowing of life, or the union of the vital principle with the material body, is the manifestation of a power superior to that displayed in the formation of an organ or the combination of many organs, or construction of the most complex animal mechanism. It is not, therefore, a greater power that we see in operation, but a power manifesting itself in the perfect and successive adaptation of one thing to another—of vitality and organization to inorganic matter.

In contemplating the chain of animal creation, we observe that even now there are parts of the earth's surface which are marshy, and insalu-

brious; and that these are the places inhabited by amphibious and web-footed animals,—such as are suited to the oozy margins of swamps, lakes, or estuaries. It is most interesting to find that when the remains of animals, of similar construction, are found in the solid rocks, the geologist discovers, by other signs, that at the period of the formation of these rocks, the surface was flat, and that it produced such plants as imply a similar state of the earth to these swampy and unhealthy regions.

We thus mark changes in the earth's surface, and observe, at the same time, corresponding changes in the animal creation. We remark varieties in the outward form, size, and general condition of animals, and corresponding varieties in the internal organization,—until we find Man created, of undoubted pre-eminence over all, and placed suitably in a bounteous condition of the earth.

Most certainly the original crust of the earth has been fractured and burst up, that its contents might be exposed; that they might be resolved and washed away, by the vicissitudes of heat, cold, and rain: mountains and valleys have been formed; the changes of temperature in the atmosphere have ensured continual motion and healthful circulation: the plains have been made salubrious, and the damps which hung on the low grounds have gathered on the moun-

tains in clouds, so that refreshing showers have brought down the soil to fertilize the plain. In this manner have been supplied the means necessary for man's existence, and objects suited to excite his ingenuity, and to reward it, and fitted to develope all the various properties both of his body and of his mind. And thus it is "that the invisible things from the creation of "the world are perceived by what we do see."

There is extreme grandeur in the thought of an anticipating or prospective intelligence: in reflecting that what was finally accomplished in man, was begun in times incalculably remote, and antecedent to the great revolutions which the earth's surface has undergone. Nor are these conclusions too vast to be drawn from the examination of a part so small as the bones of the hand; since we have shown that the same system of parts which constitutes the perfection of that instrument adapted to our condition, had its type in the members of those vast animals which inhabited the bays, and inland lakes of a former world. If we seek to discover the relations of things, how sublime is the relation established between that state of the earth's surface, which has resulted from a long succession of revolutions, and the final condition of its inhabitants as created in accordance with these changes.

Nothing is more surprising to our measure of

time, than the slowness with which the designs of Providence have been fulfilled. But as far as we can penetrate by the light of natural knowledge, the condition of the earth, and with it man's destinies, have hitherto been accomplished in great epochs.

We have been engaged in comparing the structure, organs, and capacity of man and of animals; we have traced a relation; but we have also observed a broad line of separation between them—man alone capable of reason, affection, gratitude, and religion: sensible to the progress of time, conscious of the decay of his strength and faculties, of the loss of friends, and the approach of death.

One who was the idol of his day, has recorded his feelings on the loss of his son, in nearly these words,—"We are as well as those can be who have nothing further to hope or fear in this world. We go in and out, but without the sentiments that can create attachment to any spot. We are in a state of quiet, but it is the tranquillity of the grave, in which all that could make life interesting to us is laid." If in such a state, there were no refuge for the mind, then were there something wanting in the scheme of nature:—an imperfection in man's condition at variance with the benevolence which is manifested in all other parts of animated nature.

I have sometimes thought it possible, that a greatly extended survey of nature may humble too much our conceptions of ourselves; and that this requires to be corrected by the study of things more minute, and in which we are more directly concerned: by dwelling on the perfection of the frame of the animal body and the marvellous endowments of the living properties. When we have formed some estimate of the immensity of the heavenly bodies, we are struck with admiration in following the successive advances made in the science:—an improvement in the curves of the glasses of the telescope, a new mode of polishing the reflecting surfaces, a change in the chemical composition of the glasses, or a more perfect adjustment of their dispersive powers—leads to the discovery of circle beyond circle of worlds interminably. We fan the imagination and labour to comprehend the immensity of the creation, and fall back with the impression of the littleness of all that belongs to us: our lives seem but a point of time, compared with the astronomical and geological periods, and we ourselves, as atoms, driven about, amidst unceasing changes of the material world.

But it has been shown, that whether we take the animal body as a single machine, or embrace in the survey the successive creation of animals, conforming always to the improving condition of

the earth, there is nothing like chance or irregularity in the composition of the system. In proportion indeed as we comprehend the principles of mechanics, or of hydraulics, as applicable to the animal machinery, we shall be satisfied of the perfection of the design. If anything appear disjointed or thrown in by chance, let the student mark that for contemplation and experiment, and most certainly, when it comes to be understood, other parts will receive the illumination, and the whole design stand more fully disclosed.

The extension of knowledge has not necessarily the effect of raising the mind to more consolatory contemplations. We may quote the ancient philosopher in contrast with the modern. The former, having nothing in his mind to draw him from observing the just relations of human beings to the world, but, on the contrary, seeing every thing suited to man or subordinate, thinks of him "as a little God harboured in a humane body." But when by science, and the aid of instruments, or "the ingenuity of the hand," vision is extended to things too remote perhaps, or too minute, to fall within our natural sphere; when instead of the extended plane, and visible horizon of the stable earth, our globe is thought of as a ball rolling through space, amidst myriads besides, greater than it: the expression is excuseable that—"the earth with man upon it

does not seem much other than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro, a little heap of dust."

We may consider man, before the lights of modern philosophy had their influence on his thoughts, as in a state more natural; in as much, as he yielded unresistingly to those sentiments which directly flow from the objects and phenomena around him. But when that period of society arrived, in which he made natural phenomena the subjects of experiment or of philosophical enquiry, then was there some danger of a change of opinion, not always beneficial to his state of mind. This danger does not touch the philosopher so much as the scholar. He who has strength of mind and ingenuity to make investigations into nature, will not be satisfied with the discovery of secondary causes—his mind will be enlarged, and the objects of his thoughts and aspirations become more elevated. But it is otherwise with those not themselves habituated to investigation, and who learn, at second hand, the result of those enquiries. If such a one sees the fire of heaven brought down into a phial, and materials compounded, to produce an explosion louder than the thunder, and ten times more destructive, the storm will no longer speak an impressive language to him. When in watching the booming

waves of a tempestuous sea along the coast, he marks the line at which the utmost violence of the ocean is stemmed, and by an unseen influence thrown back, he is more disposed to feel the providence extended to man, than when the theory of the moon's action is, as it were, interposed between the scene which he contemplates, and the sentiments naturally arising in his breast. Those influences on the mind which are natural and just, and beneficently provided, and have served to develope the sentiments of millions before him, are dismissed as things vulgar and to be despised. With all the pride of newly acquired knowledge, his conceptions embarrass, if they do not mislead him ; in short, he has not had that intellectual discipline, which should precede and accompany the acquisition of knowledge.

But a man, possessed of genius of the highest order, may lose the just estimate of himself, from another cause. The sublime nature of his studies may consign him to depressing thoughts. He may forget the very attributes of his mind, which have privileged these high contemplations, and the ingenuity of the hand, which has so extended the sphere of his observation.

The remedy, to such a mind, is in the studies which we are enforcing. The heavenly bodies, in their motions through space, are held in their orbits by the continuance of a power, not more

wonderful or more deserving of admiration, than that by which a globule of blood is suspended in the mass of fluids—or by which, in due season, it is attracted and resolved: than that, by which a molecule entering into the composition of the body, is driven through a circle of revolutions and made to undergo different states of aggregation: becoming sometime, a part of a fluid, sometime, an ingredient of a solid, and finally cast out again, from the influence of the living forces.

Our argument, in the early part of the volume, has shown man, by the power of the hand (as the ready instrument of the mind) accommodated to every condition through which his destinies promise to be accomplished. We first see the hand ministering to his necessities, and sustaining the life of the individual. In a second stage of his progress, we see it adapted to the wants of society, when man becomes a labourer and an artificer. In a state still more advanced, science is brought in aid of mechanical ingenuity, and the elements which seemed adverse to the progress of society, become the means conducing to it. The seas, which at first set limits to nations, and grouped mankind into families, are now the means by which they are associated. Philosophical chemistry has subjected the elements to man's use; and all tend

to the final accomplishment of the great objects to which every thing, from the beginning, has pointed—the multiplication and distribution of mankind, and the enlargement of the sources of man's comfort and enjoyment—the relief from too incessant toil, and the consequent improvement of the higher faculties of his nature. Instinct has directed animals, until they are spread to the utmost verge of their destined places of abode. Man too is borne onwards; and although, on consulting his reason, much is dark and doubtful, yet does his genius operate to fulfil the same design, enlarging the sphere of life and enjoyment.

Whilst we have before us the course of human advancement, as in a map, we are recalled to a nearer and more important consideration: for what to us avail all these proofs of divine power—of harmony in nature—of design—the predestined accommodation of the earth, and the creation of man's frame and faculties, if we are stopped here? If we perceive no more direct relation between the individual and the Creator? But we are not so precluded from advancement. On the contrary, reasons accumulate at every step, for a higher estimate of the living soul, and give us assurance that its condition is the final object and end of all this machinery, and of these successive revolutions.

To this, must be referred the weakness of the

frame, and its liability to injury, the helplessness of infancy, the infirmities of age, the pains, diseases, distresses, and afflictions of life—for by such means is man to be disciplined—his faculties and virtues unfolded, and his affections drawn to a spiritual Protector.

Some have suggested the unworthy thought that the Author of our Being has in his benevolence merely nursed and cradled us during the decline of life, as in the first dawn of it: and, therefore, they will have it, those hopes, and that longing, for after life which all entertain are implanted in us. But such an hypothesis has no support from the extended survey of nature or of man's condition. There is no analogy in its favour: for as the members of the natural body have each their relation, and nothing is isolated or alone: as every instinct, or sense, has an end, or design: and every emotion in man has its object and direction; we must conclude that the desire of communing with God is but another test of his being destined for a future existence, and the longing after immortality the promise of it.

ADDITIONAL ILLUSTRATIONS.

ADDITIONAL ILLUSTRATIONS.

THE MECHANICAL PROPERTIES OF THE SOLID STRUCTURE OF THE ANIMAL BODY CONSIDERED.

It has been shown in the first chapter that solidity and gravity are qualities necessary to every inhabitant of the earth; the first, to protect it; the second, that the animal may stand, and possess that resistance, which shall make the muscles available for action.

The first material to be taken notice of, which bestows this necessary firmness on the animal textures, is the *cellular substance.* This consists of delicate membranes, which form cells; these cells communicate with each other, and the tissue thus composed enters every where into the structure of the animal frame. It constitutes the principal part of the *medusa,* which floats like a bubble on the water; and it is found in every texture of the human body. It forms the most delicate coats of the eye; and gives toughness and firmness to the skin. It is twisted into ligaments, and knits the largest bones: it is the medium between bone, muscle, and blood-vessel: it produces a certain

firmness and union of the various component parts of the body while it admits of their easy motion. Without it, we should be rigid, notwithstanding the proper organs for motion; and the cavities could not be distended or contracted, nor could the vessels pulsate.

But the cellular texture is not sufficient on all occasions, either for giving strength or protection: nor does it serve to sustain the weight, unless the animal lives suspended in water, or creeps upon the ground. Shell fish have their strong covering for a double purpose: to keep them at the bottom of the sea, and to protect them when drifted by the tide against rocks. Animals of the molluscous division, which inhabit the deep sea, and float singly, or in groups, as the genus scalpa, have a leathern covering only: because they are not liable to the rough movements to which the others are subject, in the advancing and retiring tides. The scalpa, simple as it is in structure, for it presents the appearance of a mere bag, having two orifices, capable of opening and closing by valves, possesses at once all the functions of digestion, respiration, reproduction, and, more strange than any, locomotion. We may see the provisions, in its outward form and substance, and its mode of life, for the place that it holds: from floating or swimming at will, it is one of the "natantes;" and it is further distinguished, from being furnished with a leathern

coat, by the term "tunicata." Now it is worthy of admiration, that although unprovided with exterior members, and having only two or three muscular bands attached to its outer covering, it can move from place to place, by merely taking in and throwing out the water in which it floats; and the same operation is sufficient to supply it with its food, and carry on the process of respiration.

The hermit crab gives us a demonstration of the necessity for a protecting covering. The tail or hinder part, has no crust or shell upon it, as the body and claws have; and therefore this animal has to seek a suitable dwelling place,—some empty univalve shell, into which it insinuates its tail, and from which its head and arms project: with this power of selecting a house, it removes when it has outgrown the shell in which it has dwelt, and is seen trying the empty shells upon the shore, and contending with others of its own species. Surveying these instances, we cannot resist the conviction of the fine adaptation of the sensibilities and instincts of animals to their forms and substances.

With all this, when we look to animals of more complex structure, and possessing a distinct system of muscles, we perceive the necessity for some harder and more resisting material being added, if the weight is to rest on points or extremities; or if the muscular activity is to be

concentrated. And nature has other means of supplying the fulcrum and lever, besides the bones, or true skeleton, which we have been examining in the first part of this volume. Perhaps we shall find that there may be a system of solid parts superior even to what we have been studying in the *vertebrata.*

The larvæ of proper insects and the annelides have no exterior members for walking or flying: but to enable them to creep, they must have points of resistance, or their muscles would be useless. Their skins suffice; and they are hardened by a deposit within them, for this purpose. But if this skin were not further provided, it would be rigid and unyielding, and be no substitute for bone. These hardened integuments are, therefore, divided into rings; to these the muscles are attached; and as the cellular membrane between the rings is pliant, the animals can creep and turn in every direction.

Without further argument, we perceive how the skin, by having a hard matter deposited in it, is adapted to all the purposes of the skeleton. It is worthy of notice that some animals, still lower in the scale,—the tubipores, sertularia, cellularia, &c. exhibit something like a skeleton. They are contained within a strong case, from which they can extend themselves; whilst the corals and madrepores, on the other hand, have a central axis of hard material, the

soft animal substance being, in a manner seated upon it. But these substitutes for the skeleton are, like shell, foreign to the living animal; although in office they may resemble bone, in sustaining the softer substance and giving form.

In the proper insect, I should say that there is a nearer approach to a skeleton, were it not that the apparatus is more perfect than in some of the animals which have a true skeleton. The resisting material is here deposited externally: and is converted to every purpose which we have seen attained by means of the skeleton. Distinct members are formed, with the power of walking, leaping, flying, holding, spinning, and weaving. The hardened integuments, thus articulated and performing the office of bones, have, like them, spines and processes; with this difference, that their aspect is towards the centre, instead of projecting exteriorly. Were we to compare the system of "resisting parts" in man and in the insect, we should be forced to acknowledge the mechanical provisions to be superior in the lower animal! The first advantage of the skeleton (as we may be permitted to call the system of hard parts in the insect) being external and lifeless, is, that it is capable of having greater hardness and strength bestowed upon it, according to the necessities of the animal, than can be bestowed upon bone; true bone, being internal and growing with the animal, is pene-

trated with blood vessels; and therefore must be porous and soft. The next advantage in the exterior crust or skeleton is mechanical. The hard material is strong to resist fracture, and to bear the action of muscles, in proportion to its distance from the centre: for the muscles in the insect, instead of surrounding the bones, as in the higher animals, are contained within the shell, and the shell is, consequently, so much the further thrown off from the axis of the limb.

When considering the larger vertebral animals, we had reason to say that there is a correspondence between the resistance of the bones and the power of the muscles; and we may indulge the same reflection here. As the integument covering the insect is much harder than bone, so are the muscles stronger, compared with the muscles of the vertebrata. From the time of Socrates, comparisons have been made between the strength of the horse and of the insect; to the obvious superiority of the latter.

As goodly a volume has been written on the muscles of a caterpillar as has ever been dedicated to the human myology. A very minute anatomical description has been made of the caterpillar which feeds upon the willow; and here we see that the annular construction of the hard integument determines the plan of the whole anatomy: the arrangement of the muscles, and the distribution of the nerves. Each ring

has its three sets of muscles; direct, and oblique; traversing and interweaving, but yet distinct and symmetrical; and all as capable of being minutely described as those of the human body have been by Albinus.* Corresponding with these muscles, the system of nerves is delicately laid down. In short, we allow ourselves to be misled in supposing that animals, either of minute size or low in the scale of arrangement, exhibit any neglect or imperfection. Even if they were more simple in structure, the admiration should be the greater: since they have all the functions in full operation which are necessary to life.

We may perceive that a certain firm substance, calculated to sustain the more strictly living part, and to give strength, may be traced through all living bodies. In the vegetable it is the woody fibre; and there, sometimes, as if to mark the analogy, we may find silicious earth deposited instead of the phosphate and carbonate of lime of the animal structure. In the lower animals we find membranes capable of secreting a solid material; and although in some instances the substance is like leather or cartilage, it is in general earthy, and for the most part, consists of carbonate of lime. But when elasticity, as well as general resistance, is necessary, cartilage is

* The work referred to is by Lyonnet, who reckons four thousand and sixty one muscles in this caterpillar.

employed, which is a highly compressible and elastic substance. Thus, fishes have a large proportion of cartilage in their bones; and some from having it in greater quantity, have been called cartilaginous, in distinction to the osseous or true fishes. The cartilaginous and elastic skeleton comes into use in an unexpected manner in the fish: when the salmon or trout leaps from the water, the muscles of one side first bend the spine; as they relax, the spine recoils: hence its elasticity assists the action of the muscles of the opposite side: and thus these two forces combine to give a powerful stroke with the tail on the water, and the fish makes its bound.

MECHANICAL PROPERTIES OF BONE OR OF THE TRUE SKELETON.

These considerations lead us the more readily to understand the composition of bone. It is combined of three parts having different properties,—membrane, phosphate of lime, and cartilage. By these various substances being united in its texture, bone is enabled to resist stretching, compression, and tortion. If there had been a superabundance of the earthy parts, it would have broken like a piece of porcelain; and if it had not possessed toughness and some degree of elas-

ticity, it would not have enabled a man to pull and push and twist.

Looking to the dense texture of bone, we should hardly suppose that it was elastic. But if ivory be possessed of elasticity, this property cannot be denied to bone. Now if a billiard ball be put upon a marble slab which has been recently painted, a very small spot will mark the point of contact; but if we let the ball drop upon the marble from a height, we shall find the spot much larger, because the elasticity of the ivory has permitted the ball to yield, and momentarily to assume an oblate spheroidal form.

When a new principle is admitted into a complex fabric, the utmost ingenuity can hardly anticipate all the results. Elasticity is extensively employed in the machinery of the animal body; and to show how finely it must be apportioned, we shall take the illustration of a bridge built with iron instead of stone, and having a certain swing and elasticity. It lately happened that a bridge of this kind fell, in very curious circumstances,—by the marching of a body of soldiers over it. Now the bridge was calculated to sustain a greater weight than this body of men: and had they walked tumultuously over it, it would have withstood the pressure. But the soldiers marching to time, accumulated a motion, consequent on the elasticity of the material, which added to their weight, broke it down.

This leads us to form a conception of the necessity of the fine adjustment of the different qualities belonging to the solid material in the animal fabric; not merely to enable it to sustain the incumbent weight, or to resist transverse or oblique impulses, but to withstand the frequent, and regularly repeated forces to which it may be subject in the various actions of the body. It gives interest to this fact, that there is hardly a bone which has not a constitution of its own, or a disposition of its material, adjusted to its place and use: the heel bone, the shin bone, the vertebræ, and the bones of the head, all differ in their mechanical construction.

Let us compare the machinery of some complicated engine with the mechanical properties in an animal body, that we may comprehend what is most truly admirable in the latter. Suppose the engineer has contrived a steam carriage; that he has calculated, with the utmost possible precision, the power of the steam, the pressure of the atmosphere, the strength of the tubes and cylinder, the weight to be moved, and the friction of the whole machinery. The engine at length is constructed; but it remains immoveable. After much thought, the cause of the impediment is discovered, the pressure is eased, or the friction is diminished, and to the admiration of the beholders the carriage actually moves—till a pipe bursts: but, this is mended, the whole is im-

proved, and a day is appointed for a great trial; the engine now runs for half a mile, and first a bolt is shaken loose, then a spring snaps; but, at length, with renewed ingenuity and labour and much correction, after a few months, it actually runs a stage. We have here, by this comparison, a proof how much is to be admired even in the mere machinery of the animal frame, before the powers of life are measured out to it: such for example as the force of the heart to propel the blood; the resistance of the tubes to the circulating fluids; the proportioning of the strength of the limbs to the weight of the body, or of the power of the muscles to the length of the bones, as levers; the flexibility of the joints; the firmness of the bones to resist pressure or weight; their elasticity to prevent concussion and fracture. In the animal body there is no accident occurring from disproportioned forces,—the active and resisting powers are so finely balanced; no second trial is wanted, to increase the power, or strengthen the levers, or add to the elasticity of the springs—it is at once perfect; perfect to its end. But to understand this fully, and the adaptations in the constitution of the bones, we must proceed a little deeper in our investigation.

Perfect security against accidents in the animal body, and in man especially, is not consistent with the scheme of nature. Without the

precautions and the continued calls to exertion, which danger and the uncertainty of life produce, many of the faculties of the mind would remain unexercised. Whence else would come courage, resolution, and all the manly virtues? Take away the influence of the uncertain duration of life, and we must suppose also a change in the whole moral constitution of man. Whether we consider the bones as formed to protect important organs, as in the skull: or to be levers for the attachment of the muscles, as in the limbs: or in both capacities, as in the texture of the chest: while they are perfectly adapted to their function, they are yet subject to derangements from accident. The mechanical adaptations are sufficient to their ends, and afford safety, in the natural exercises of the body. To these exercises there is an intuitive impulse, ordered with a relation to the frame of the body; for we are deterred from the excessive or dangerous use of the limbs by the admonitions of pain. Without such considerations, the reader would fall into the mistake that weakness and liability to fracture implied imperfection in the frame of the body: whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident; and to become in the course of life, more and more fragile, until by

some failure in the frame-work or vital actions, life terminates.

The bones of the extremities are called hollow cylinders. Now, after having convinced ourselves of the necessity of this formation for the bones of the limbs, as it is that which combines strength with lightness, we may find upon a more particular examination, that they are, on the whole, extremely varied in their shapes: and we may be, at last, prone to believe that there is much chance or irregularity in the forms of these bones. But such a conception is quite inconsistent with a correct knowledge of the skeleton. As this notion, however, is very commonly entertained, and leads to further mistakes, we shall take pains to show,—first, why the bones are hollow cylinders; and, in the second place, why they vary in their shape, so as to appear to the superficial observer irregular.

The reasoning that applies to the hollow cylindrical bone, serves equally to explain the admirable structure of many other natural forms, as that of a quill, a reed, or a straw: and this last example will remind us of the unfortunate man, who being drawn from his cell before the Inquisition, and accused of denying that there was a God, picked up a straw, that had stuck to his garments, and said, "If there were nothing else "in nature, to teach me the existence of a Deity, "this straw would be sufficient."

It hardly requires demonstration to prove that, with a given mass of material from which to make a pillar or column, the hollow cylinder will be the form of greatest strength. The experiments of Du Hamel on the strength of beams, afford us the best illustration how the material should be arranged to resist transverse fracture. When a beam rests on its extremities, bearing a weight upon its centre, it admits of being divided into three portions; each being in a different condition with regard to the weight. The lower part resists fracture by its toughness: the upper part, by its density and resistance to compression: and the portion between these is not acted upon at all. This middle part might, therefore, be taken away without any considerable weakening of the beam: or it might be added to the upper or the lower part with great advantage. It can readily be understood how a tougher substance added to the lower part, would strengthen the beam: we see it in the skin laid along the back part of the Indian's bow; or in the leather of a carriage spring. Again, the following is a beautiful experiment to demonstrate the quality in the timber that resists the weight at the upper portion of the beam: if a portion, amounting to nearly a third part, of the beam be cut away, and a harder piece of wood be nicely let into the space, the strength will be increased; because the hardness of this piece of wood resists compression. This

experiment I like the better, because it explains a very interesting peculiarity in the different densities of the several parts or sides of the bones.

In reading anatomical books, we are led to suppose that the various forms of the bones result from the pressure of the muscles which surround them. This is a mistake. Were we to consider such to be the true explanation, it would not only be admitting an imperfection, but we should expect to find, if the bones yielded in any degree to the force of the muscles, that they would yield more and more with the increased power of the muscles, and be ultimately destroyed. There is nothing, however, more admirable in the living frame, than the relation established between the muscular power and the strength or capacity of passive resistance in the bones. The deviations from the cylindrical forms are not irregularities. If we take for our example the bone which, of all others, deviates furthest from the cylindrical shape—the tibia or shin bone, we shall have the best demonstration of the correspondence between the shape of the bone and the force which it has to sustain.

When we consider the direction of the force, as we put the foot to the ground in walking, running, or leaping, and in all the powerful exertions where the weight of the body is thrown forwards on the ball of the great toe, it must appear that

the pressure against the shin bone is chiefly on the anterior part. Accordingly, there can be no doubt, that if the tibia were a perfect cylinder, it would be subject to fracture even from the mere force of the body itself when thrown upon it. But if the column be rendered stronger by the material being accumulated to a distance from the centre, we readily perceive how an anterior spine, or ridge should be formed upon the tibia: and if we attend to the internal structure of that spine, we shall find that it is much denser and stronger than the rest of the bone. We cannot therefore deem either the form or the density of this ridge, a thing of accident, since it so perfectly corresponds with the experiment of Du Hamel which we have described, where the dense piece of wood being let into the piece of timber, was the means of increasing its power of resisting transverse fracture. With the knowledge of these facts, were we to proceed to examine all the different bones of the skeleton, we should find that every where the form had a strict relation either to the motion to be performed, or the strain to which the bone was most exposed.

In comparing the true bones of the higher animals with the coverings of insects, we observed the necessity for the porous structure of the former, and their inferiority of strength, resulting from this cause. If it be necessary for a bone to be very dense, it will, in that case,

no longer possess the power of re-union or reproduction when it breaks: it will not re-unite upon being fractured, and if exposed, it will die. Here, then, is an obvious imperfection. The bones of animals cannot, in this manner, be made capable of sustaining great weight, without losing a property necessary to their existence—that of restoration on being injured. And even were the material very much condensed, it does not appear that the phosphate of lime, united as it is with the animal matter, is capable of sustaining any great weight. This accordingly limits the size of animals. It may, perhaps, countenance the belief that animals bear a relation, in their size and duration of life, to the powers and life of man—that those of the greatest dimensions existed in a former condition of the world. We allude only to such animals as have their huge bulk resting on extremities: for with respect to the whale, it lies out supported in the water. Some of the great fossil animals, found in the secondary strata, are estimated to have been seventy feet in length; and they had extremities. But the thigh and leg did not exceed eight feet in length, while the foot extended to six feet; a proportion which implies that the extremities assisted the animal to crawl, rather than that they bore its weight, like the extremities of the mammalia. However, we find that in the larger terrestrial animals, the material of

the bones is dense, and that their cavities are filled up; the diameters of the bones of the extremities, with their spines and processes, being remarkably large. Nothing can be conceived more clumsy than the bones of the megatherium. Hence it really appears that nature has exhausted her resources with respect to this material; and that living and vascular bone could not be moulded into a form to sustain the bulk and weight of an animal much superior to the elephant, mastodon, and megatherium.*

With regard to the articulation of the bones at the joints, we cannot mistake the reason why

* The subject may be illustrated in this manner:—" A soft " stone projecting from a wall, may make a stile strong enough " to bear a person's weight; but if it were necessary to double the " length of the stile, the thickness must be more than doubled, " or a freestone substituted: and were it necessary to make this " freestone project twice as far from the wall, it would not " be strong enough to bear a proportioned increase of weight, " even if it were doubled in thickness: granite must be placed " in its stead; and even the granite would not be capable of " sustaining four times the weight which the soft stone bore in the " first instance. In the same way the stones which form an arch, " of a large span, must be of the hardest granite, or their own " weight will crush them. The same principle is applicable to " the bones of animals. The material of bone is too soft to ad- " mit of an indefinite increase of weight; and it is another illus- " tration of what was before stated, that there is a relation " established through all nature: that the structure of the very " animals which move upon the surface of the earth is propor- " tioned *to its magnitude*, and the gravitation to its centre."— Animal Mechanics.

the surfaces of contact between them are enlarged. The expansion of the ends of the bones, obviously makes them sit more securely upon each other. Now this advantage is gained without the motion of the joint being impeded. In machinery it is found that, if the pressure be the same, the extension of the surfaces in contact does not increase the friction. If, for example, a stone or a piece of timber, of the shape of a book or a brick, be laid upon a flat surface, it may be drawn across it with equal facility, whether it rests upon its edge or upon its side. The friction of the bones, which enter into the structure of the knee joint, is not increased by their greater diameter: while obvious advantages are gained by their additional breadth; the ligaments which knit these bones give more strength than they otherwise would, and the tendons which run over them, being removed to a distance from the centre, have more power.

OF THE MUSCULAR AND ELASTIC FORCES.

The muscular power is contrasted with the elastic, as being a property of motion possessed exclusively by a living part. We acquiesce in the distinction, since the muscular fibre ceases to have irritability or power in death, while

elasticity continues in the dead substance. But yet there is a property in the elasticity of the living body which cannot be retained after death. To illustrate this, we shall take the instance of the elasticity in the catgut string of a harp, and suppose that it is screwed tight, so as to vibrate in a given time, and to sound the note correctly; if that string be struck rudely, it will be put out of tune; that is, it will be stretched and somewhat relaxed, and no longer vibrate in time. But this does not take place in the living fibre; there is in it a property of restoration. If we see the tuner screwing up the harp string, and with difficulty, and after repeated attempts,—trying it with the tuning fork, bringing it to its due tension, and with his utmost acquired skill restoring it to its former elasticity, we have a demonstration of how much life is performing, after every effort or exertion, in the fibres of the animal frame. The more powerful the mechanical parts of the body are, the more carefully is the proper tension of the tendons, ligaments, and heart-cords preserved.

Or we may take the example of a steel spring. A piece of steel, heated to a white heat, and plunged into cold water, acquires certain properties; and if heated again to 500° of Fahrenheit, it becomes elastic; possessing what is called a "spring temper," so that it will recoil and vibrate. But if this spring be bent in a degree

too much, it will be deprived of part of its elasticity. Should the parts of the living body, on the other hand, be similarly used, they have a power of restoration, which the steel has not.

If a piece of fine mechanism be made perfect by the workman, it may be laid by and preserved: but it is very different with the animal body. The mechanical properties of the living frame, like the endowments of the mind, will suffer deterioration, if they lie idle. If, by some misfortune, a limb be put out of use, not only will the power of the muscles become rapidly diminished, which every one will acknowledge, but the strength of resistance in its different textures will be lost, the bones, tendons, and ligaments will quickly degenerate.*

* This subject is illustrated in the Essay on Animal Mechanics, Part II.

On the Position of the Head of Animals and its Relation to the Spine: to Illustrate the Proposition, that ALL PARTS OF THE SKELETON CORRESPOND WITH EACH OTHER, AND THAT THE VARIATIONS IN THEIR FORM DEPEND ON THE FUNCTIONS.

In the text, in speaking of the upper or anterior extremity, it has been shown that the changes of form exhibited in different animals may be referred to one principle—the adaptation of the parts to their proper uses. The head may be considered, in certain animals, as performing in some measure the office of hands. Now if we adopt this view, we shall be able to judge how far it holds true that the centre of the skeleton to which the head belongs, remains permanent in its form, compared with the extreme parts. It has been stated as the opinion of some naturalists, that the varieties in the conformation of the skeleton are to be accounted for by a law which preserves the central parts permanent, whilst the extremities are incident to change. I shall controvert that opinion, and show that the spine and head, whilst they retain their offices of protecting the brain and spinal marrow, and are permanent in regard to them, vary in

the shapes of their processes and in their relations. Pursuing this idea, we shall be able to account for the characteristic forms of the larger quadrupeds.

The principle, then, which will guide us here, as it will, indeed, in a more universal survey of animal nature, is, that the organization varies with the condition or the circumstances in which the animals are placed—that they may feed and multiply. If we take into consideration any of the great functions on which life depends, we shall perceive that the apparatus, or the mode of action of the parts is altered and adapted to every changing circumstance. Digestion, for example, is the same in all animals; but there is an interesting variety in the organization: for the stomach varies in its form, and in the number of its cavities, in the quadruped, or bird, or fish, or insect, in accordance with the nature of the food which it receives. The variation does not depend upon the size or form of the animal, but is adapted purely to the conversion of its particular food into nourishment. We shall find the gizzard in a fish or in an insect, as perfect as in the fowl. So the decarbonization of the blood is the same process in all living animals: but the mode in which the respiration is performed varies according to circumstances; and the apparatus is especially modified and adjusted to the atmosphere or to the water.

But although the organs subservient to the grand functions,—the heart and blood vessels, the lungs, the stomach, be variously adapted to the different classes of animals, they change much less than the parts by which animals are enabled to pursue their prey or obtain their food. Their extremities, by which they walk, or run, or creep, or cling, must vary infinitely. And so their teeth and horns, and the position of their head, and the strength of their neck, exhibit nearly as much variety as their proper extremities; because these parts likewise must be adapted to their different modes of obtaining food, or of combating their enemies. Let us then, in pursuing this principle, observe the meaning of the forms of the more remarkably shaped animals.

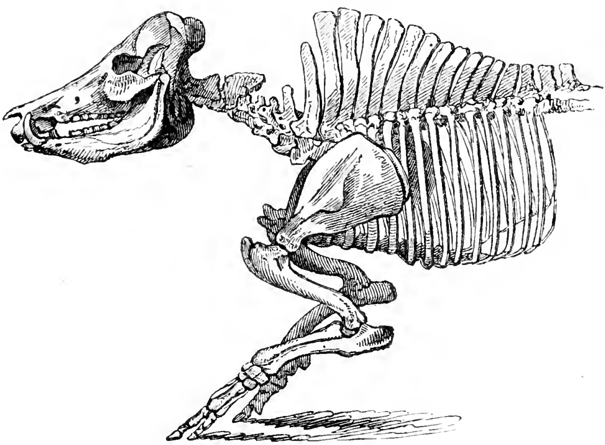
When we look upon the boar's head,* we

* This is a sketch of the dried head of the Sus Ethiopicus

may comprehend from it alone something of his habits; we may see what must be the direction in which he will employ his strength. He feeds by digging up roots, and the instruments by which he does this, are also those of his defence; the position of the tusk defends the eye in rushing through the underwood; but the formation of the skull and of the spine and the mass of muscle in the neck, all show the intention of his configuration to be, that he may drive onward with his whole weight and strength, and rend with his tusks. Accordingly, we see that the back part of the skull rises in remarkable spines or ridges for the attachment of muscles, and that corresponding with these, the spinous processes of the vertebræ of the neck and back are of extraordinary length and strength. Processes like these distinctly indicate the immense power of the muscles which pass from the neck to the head. We now understand the reason of the shortness and inflexibility of the neck: because the strength of the shoulders is directed to the

with part of the skull exposed. The tusks show what a formidable animal it has been. That which rises out of the upper jaw is of great size, and we must admire the manner in which the tusk of the lower jaw closes upon it so as to strengthen it near its root. The great size and sharpness of these tusks illustrate what is offered in the text—that the main strength of the animal must be directed towards them. The rising of the back of the head will be seen to correspond with the great height and strength of the spinous processes of the back exhibited in the next figure, taken from the wild boar of Germany.

head, and, we may say, to these large tusks. An elongated and flexible neck would have rendered these provisions useless. The characteristic form of the wild boar, then, consists in the height of the back, the shortness and thickness of the neck, the wedge shape of the head, the projection of the tusk, and the shortness of the fore legs, which must always be in proportion to the neck.



Thus we perceive that the skull, unaffected in its office for containing and protecting the brain, is yet subject to variations in its form and place in reference to its other functions; because it must be adapted, just as the extremities are, to the animal's mode of life. In the same manner, we see that the spine is permanent in its office as a tube to protect the spinal marrow, but that it

varies in its processes and articulations as they bear a reference to the skull: and that although this be the very central part of all, it varies in due degree, and is accommodated to the whole skeleton.

What a complete contrast there is between this animal and any of the feline tribe! But it is a contrast of form and motion at once referrible to their spine. In the tiger or leopard, the perfect flexibility of the body, and the almost vermicular motion of the spine, corresponds with the teeth and jaws and the free use of the paws.

The peculiarity of form in the elephant has been happily illustrated by the celebrated Cuvier: and the principle may be pursued in a

manner interesting both to the Naturalist and Geologist.

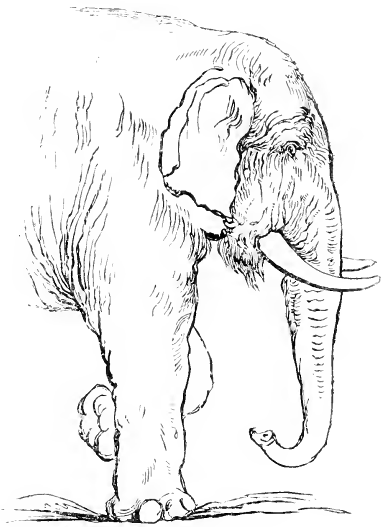
We may feel in ourselves that there is a certain projection of the spine between the shoulders, which marks the process of the "*vertebra prominens.*" When we stoop forward, as in reading a book which lies upon the table, we may feel a ligament extending from this process to the back of the head. This ligament suspends the head and relieves the muscles. But as man, for the most part, carries his head balanced upon the extremity of the spine, or can vary its relation under fatigue, the strength of that suspensory ligament is not to be compared with the corresponding part in quadrupeds; where, from the horizontal position of the spine, the head always hangs: and where there would be a great waste of muscular exertion, but for the interposition of this elastic ligament. It is long and strong in the horse; and the admirable thing is the accurate adjustment of the elasticity of this ligament to the weight and position of the head. The head is nicely balanced by it, as on a steel-yard. With this circumstance in our mind, let us observe the peculiar form of the elephant.

1. We begin, again, as in treating of the boar, by observing the teeth. Now, one grinder tooth of the elephant weighs seventeen pounds;* and

* The natural tooth weighed seventeen pounds, the fossil tooth sixteen and a-half pounds.

there are four of these in the skull, besides the rudiments of others. 2. We next observe how admirably these teeth are suited to sustain great pressure and attrition. 3. The jaws must be provided in such a manner as to give a deep socketing to the teeth: and the bones must be of a sufficient size to give lodgement to muscles strong enough to move this grinding machine. 4. The animal must have its defence too. Now each of the tusks sometimes weighs as much as one hundred and thirteen pounds: and from their projecting so much, they may be considered as placed at the extremity of a lever. 5. If this enormous and heavy head had hung on the end of a neck having anything like the proportion of that of the horse, the pressure would have been inordinate on the anterior extremities; and more than four times the expenditure of muscular power would have been necessary to the motion of the head. 6. What has been the resource of nature? There are seven vertebræ of the neck in this animal, the same number that we find in the giraffe; but they are compressed in a very remarkable manner, so as to bring the head close upon the body: and thus the head is, as it were, a part of the body, without the interposition of any neck. 7. But the animal must feed: and as its head cannot reach the ground, it must possess an instrument like a hand, in the proboscis,—to minister to the mouth, to grasp the

herbage and lift it to its lips. Thus we perceive that the form of the elephant, as far as regards



the peculiar character in the shoulders and head, the closeness of the head to the body, the possession of the proboscis, and the defence of that proboscis by the projecting tusks, is a necessary consequence of the weight of the head, and, indeed, of the great size of the animal.

We may carry the inquiry a little further to the effect of elucidating a very curious part of natural history. The mastodon is the name of an extinct animal, which must have been nearly of the same size as the elephant. It has received that name from the early familiarity of Naturalists with the teeth ; which have upon

their surfaces of contact mammillary-shaped projections. It was supposed, at one time, that these teeth belonged to a carnivorous animal. But on a portion of the upper jaw being found with the teeth preserved in it, it admitted of this course of reasoning. In the upper maxillary bone of all vertebrated animals, there is a hole which transmits a branch of the fifth pair of nerves (see p. 161). This nerve goes to the upper lip. When there is the addition, however, as in the elephant, of a great proboscis, since that organ possesses its sensibility through this nerve, not only will the nerve itself be proportionably large, but the hole through which it is transmitted will be increased in its diameter. Hence it follows that when we possess a portion of the bones of the upper jaw we can infer, by the greater size of this hole, that the nerve supplied more than the lips—that the animal, as in the case of the mastodon, had a proboscis, and was a species of elephant.

It has been more lately discovered by our conservator in the College of Surgeons, Mr. Clift, that judging from the teeth, and including in the survey the extinct as well as the living animals, there was a regular series, from the Asiatic elephant to the mastodon of the Ohio. If we consider that tooth to be the most perfect, which is most capable of resisting attrition, either from the mode of its growth or its structure, we shall

begin with the great Asiatic elephant. The grinding tooth of this animal consists of alternate layers of the ivory and enamel, and, from the closeness with which these parts are laid together, of a third portion, called crusta petrosa. The tooth of the African elephant is easily distinguished, by the wide interstices between the layers of enamel. On the banks of the Irawadi, the tooth of a new species of mastodon is found, where the mammillary processes are so high, and the interstices are so deep, that if a section of it be made, it resembles the tooth of the African elephant, and stands intermediate between that and the mastodon giganteum of North America.

Let us consider this principle in another light, and see how the neck and head are accommodated for feeding, when there is no trunk or proboscis, and when the animal has a short neck. The elk is a strange, uncouth animal, principally from the setting on of its head. The weight of the horns is enormous: and if the head and horns were placed at the extremity of an elongated neck, it would be preposterous, and, in fact, they would overbalance the body. It is for this reason, we must presume, that the head is so curiously approximated to the trunk. When we observe, in the next place, the want of relation between the fore legs and the neck, that the legs are of great length, while the neck is ex-

tremely short, it is interesting to find that the animal does not browse upon the herbage at its

feet, but feeds off the sides of the rocks. A very remarkable proof of the incapacity of this animal to feed in the common way was afforded by an accident which befell a fine male specimen confined in the Zoological Gardens. To reach the ground, on which his food was unintentionally scattered, he had to extend out his fore legs laterally; in this position his foot slipped, he dislocated his shoulder, and died of the accident.

Contrasted with the elk, in a most remarkable manner, we have the giraffe; which feeds upon

the branches of lofty trees. The whole constitution and form of this animal is provided to enable it to reach high—the fore legs are long, the neck still longer, the head is remarkably small and light, and the tongue has a power of elongation which no other quadruped possesses. The tongue is, indeed, not inaptly compared with the trunk of the elephant; it can be extended seventeen inches, and twisted about, so as to resemble a long black worm; and it is used with extraordinary dexterity, in picking up a straw, as well as pulling down a branch. The anatomy of the bones of the giraffe is full of interest, as showing the accommodation in the structure, to the necessities of the animal. And, first, of the head: if we have the skulls of the giraffe and of the camel or horse before us, we are struck with the comparative delicacy of the former, and with its being cellular, and thin and light, as a paper case. Can there be any thing more obvious, than that this lightness of texture is provided in consequence of the extraordinary length of the neck; or on the consideration (if we may use the expression) that, had the skull of the giraffe been as strong and heavy as that of the horse or camel, it would have preponderated too much at the extremity of such a neck.

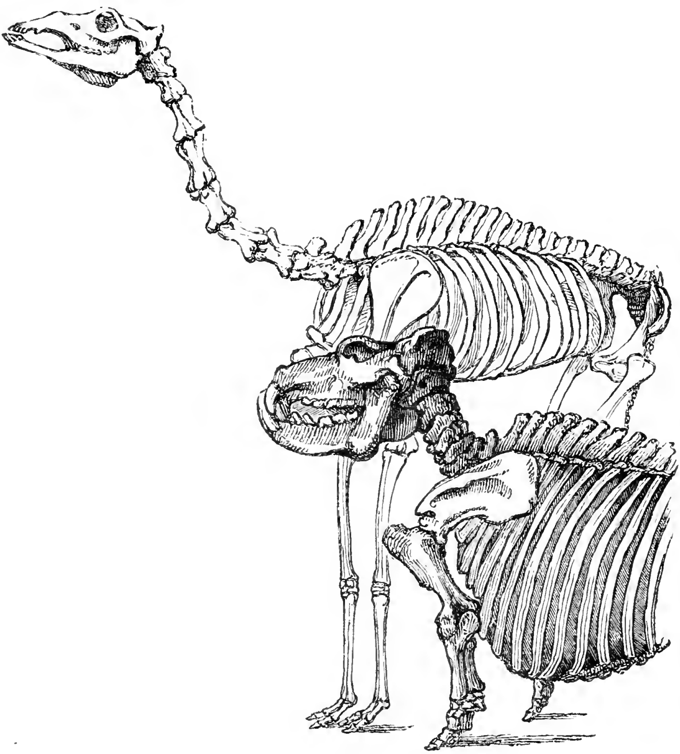
There is an accommodation also in the position of the spine. In most quadrupeds, the spine lies horizontally. If the bones had been

so placed, however, in the giraffe, the whole weight of the shoulders, neck, and head would have been thrown on the anterior extremities. But this is prevented by these anterior extremities being much longer than the posterior extremities: from which it results that the trunk has an oblique position, and a portion of the weight of the neck and head, parts which, in other creatures, are sustained altogether by the fore legs, falls, accordingly, upon the hind legs.* When we look to the ribs, we see another peculiarity, that may be accounted for on the same consideration of the length and consequent weight of the neck and head. The chest or thorax rests, of course, upon the anterior extremities: but we find that those ribs which bear the pressure, are of great comparative strength, while the ribs posterior to them present a singular contrast, by their delicacy and weakness, and their mobility in breathing. In short, it appears that the fore part of the chest, which, in a manner, intervenes between the neck and the anterior extremities, requires its compages to be particularly firm and strong, for supporting the superincumbent weight, while the motions of respiration are performed chiefly by the posterior ribs.†

* The ligamentum nuchæ in this animal extends the whole length of the spine, from the os sacrum to the skull.

† We have in the next page a sketch of the skeletons of the hippopotamus and of the camel, as they stood accidentally contrasted.

Although, in this creature, a due proportion seems to be preserved between the legs and the



neck, yet he is not suited to browse the grass,

The head of the hippopotamus is of great strength and weight, and it is appended to a short neck; in the shortness of the legs also we see the correspondence that we have had occasion to remark between the position of the head and the height of the trunk from the ground. The camel is, in every respect, a contrast. It must have rapidity and ease of motion; which is secured by the length of the extremities; and according with the extremities, are the

but to feed on the high branches of trees. In the attempt to reach the ground with his mouth, the limbs appear to be in danger of suffering dislocation. He extends his feet laterally, elevates the scapulæ, draws in the crupper, and stretches the neck, so as to present a very ludicrous figure.

Of the Horse's Head.—It is perhaps better to draw our arguments from what is familiar and constantly before us: let us, then, take the form of the horse's head. It has been affirmed that the sound of neighing in the horse, results from two cavities in the head, called the Eustachian cavities. These have been so designated because they communicate with the tubes of that name, which lead from the ear to the throat: but this is a very unsatisfactory account of the cavities in question. We are of opinion that their use is connected with this subject; that they have a relation to the weight of the head, and the length of the neck, as well as to the power of mastication of the animal. It is a very remarkable circumstance that a horse, whose "points" are approved of by the jockeys, will

length of the neck and the lightness of the head. Here, then, is the skeleton of an animal which is properly terrestrial, accommodated to all the other peculiarities of its organization, and adapted for a rapid and long continued course: the hippopotamus, on the other hand, seeks its safety in the water,—and its uncouth form and weight are suited to that element.

starve in a grass field; for by breeding and crossing they contrive, in a manner that one would almost say was artificial, to combine the incidental defects of nature, so as to make the proportions of an animal correspond with their ideas of perfection; and as they have got a notion that a short neck and a small head are excellencies in a horse, inasmuch as the weight upon the fore feet is diminished, it has sometimes happened that the neck has become too short to permit the animal to reach the ground in grazing. They observe that the splints, corns, sandcracks, whitters, inflammations, and other diseases of the horse's foot, are almost exclusively found in the anterior extremity; and they attribute these to the weight of the head and neck in conjunction with the artificial condition of the horse: for were it the shoeing and the hard roads, the effect would be equally perceptible on the hind feet. Such considerations tend to show the importance of the peculiarity now to be pointed out in the horse's skull.

On looking to the horse's head in profile, we see that its peculiar form, and especially the great depth of jaws, posteriorly, is a necessary consequence of the length of the grinding teeth. We have already noticed the magnitude and weight of the elephant's head, corresponding with the enormous teeth, which are provided for the attrition of its food. If we apply the same

rule to the head of the horse, we shall see how curiously it accounts for the peculiar shape of its skull. Like the elephant, the horse is graminivorous; and the structure of the teeth evinces how well they are calculated to masticate without wasting. To enable them to bear great pressure, they are socketted very deeply in the jaw; and as the strength of the muscles is not provided merely for closing the jaws, as in the carnivorous animals, but for grinding or drawing the jaw laterally, there is extraordinary space given for the lodgement of the muscle called masseter, which has the double action of closing the teeth and of drawing the lower jaw across the upper, as in mastication. Here then, we have the reason for that large square portion of the jaw under the ear, which peculiarly distinguishes the horse's head. Now, although the maxillary and nasal cavities are very large, the space which they occupy does not suffice to correspond with the remarkable depth of the lower jaw. In fact, the larynx and pharynx, the parts contained in this space, cannot fill up the whole depth of the head here, so that there is a great deal of room, which is neither required for the lodgement of the brain, nor for the bony cavities of the nose, nor for the pharynx, nor the trachea, but solely resulting from the great size of the jaws. Had this space been occupied by solid bone, it would have added materially to the weight of the head;

it has, therefore, been filled up by two great membranous cells, which have a communication with the cavities of the nose. On the whole, then, we may consider these large cells in the horse's head, as permitting the enlargement of the jaw bone at its back part, so as to afford a deep socketting for the grinding teeth, and a sufficient lodgement for the powerful muscles employed in mastication, without very considerably increasing the solid material of the head. Advantage is here taken of the admission of air to increase the volume and strength of the parts, as in birds, without adding to the weight. We now perceive that if the horse's skull had been formed without this provision, there would have been a positive defect, especially in the running horse; for the head would have greatly exceeded in weight, and the animal would not have been properly balanced upon his extremities; the weight upon the fore-feet would have been so much increased, as to have rendered him still more liable to those diseases of the foot to which his artificial condition subjects him.

This provision, by which the head of the horse is made lighter, has a parallel in the head of the spermaceti whale. The spermaceti whale, which is a species of the physeter or cachelot whale, has a very large head, and is remarkable for having teeth; the common whale having only whale-bone in its mouth for teeth. It would

result from the great size and length of the head, and its being loaded as it is, that the lungs could be thrown too far behind the centre of gravity, for permitting the head to be buoyant; accordingly, large cavities in the head, (twelve feet long, and four feet deep) are filled with the spermaceti, a material that is lighter than water; and the equilibrium is by this means maintained.

Although the changes in the shape of the skulls of animals are principally in their anterior part, that is, in the bones of the face, yet the slighter deviations in the back part may indicate much, if minutely scanned. For example, a portion of a skull was found, among other interesting specimens of fossil bones, in the caves of the limestone rocks, near Plymouth. It consisted merely of the condyles or articulating processes of the skull which join it to the vertebræ of the neck, together with portions of the occipital and temporal bones. Yet it could be ascertained from these that the fragment belonged to an hyæna: although its proportions were double those of the corresponding parts of the largest of the recent species. First, the high spine showed the strength of the neck; secondly, the depth and extent of the fossa or hollow for the lodgement of the temporal muscle proved that there was a remarkable mass, and consequent strength of muscle, for closing the jaws; thirdly, it belonged neither to the bear nor to the tiger, which was shown by

the extraordinary thickness and density of the whole bone. In this last respect, the portion of bone corresponded with no animal but the hyæna; for the skull of the hyæna participates in the strength which belongs so remarkably to its teeth; these being capable of breaking the strongest bones.*

In treating of this subject, Dr. Buckland has given an example of the deductions that may be drawn from the consideration of the teeth of the hyæna, not inferior to the best specimen of Cuvier's reasoning on fossil bones. While lecturing on the comparative anatomy of the skeleton, I have put the subject in this light:—"We have seen that all nature is full of life; and wherever food is to be obtained, there are animals in structure suited to reach it. Suppose that the horse is run down by the wolf, and his carcase consumed by the lesser carnivorous animals and birds of prey; there is still left in the large cylindrical bones an abundance of nutriment, which, however, these animals cannot get at. Turn your attention, then, to the skull of the hyæna. It has great clumsiness and weight contrasted with that of the dog, or the wolf, or the bear. Next, observing the teeth, you see that they are conical—which is the very form of

* This specimen is in the Museum of the College of Surgeons, and is beautifully drawn in Mr. Clift's paper in the Philosophical Transactions.

strength, and by their enamel they are case-hardened, compared with those of other animals. Proportioned to the power of resistance of the teeth are the size and density of the jaws. This hollow for the lodgement of the temporal muscle, which closes the jaws, and this prominence of the zygomatic arch, which gives attachment to another muscle of the same class, produce the extraordinary breadth of face of this very ugly animal; and corresponding with the strength of its teeth, jaws, and muscles, you see that the whole skull is thicker and denser in its texture, as if to show, by the supporting frame-work, the strength of the engine; an engine capable of breaking these powerful cylindrical bones of larger animals, and of disclosing a rich repast in the marrow."

In the earlier part of the volume, we have noticed the most remarkable peculiarities of the skeletons of birds; and we may take this opportunity of observing the relation between the form of the bird and some of the principal functions. Putting digestion and respiration, for the present, out of the question, the continuation of the species is the next in importance. Now a bird, to be buoyant and capable of flying, cannot be viviparous. If we have seen that a full stomach impeded the flight of a carnivorous bird, it is evident that it could not have carried its young within it. Is it not curiously provided,

then, that the bird shall produce its offspring by a succession of small eggs, which shall accumulate in the nest, instead of growing in the body? In short, it requires no argument to prove that the hollow bones of the skeleton, the extension of the breast-bone, the air-cells, the quill-feathers, the bill, and the laying of eggs, are all in necessary relation to each other.

Since we have spoken of the relation of the form of the skeleton to the continuation of the species, in the bird, we may for the same object revert to it in quadrupeds. In the mammalia, there is nothing more extraordinary than the deviation in the skeleton of the kangaroo from the general form. Joined to this, there is a remarkable peculiarity in the manner in which this animal produces its young. Instead of remaining within the mother for the usual period of gestation, the young, by some peculiar mode, not perfectly understood, are excluded from within the belly, and are found attached to the teats; where they hang by the mouth, covered by an exterior pouch, formed of the skin, until from being minute and shapeless things, they are matured to the degree in which the young of other animals are usually brought forth.

Now we think that the upright position of this animal (for it is the only creature except man which rests in the perpendicular), and the disproportioned magnitude of the lower part of its

body, are the reasons of the peculiarity in its mode of gestation. Without entering far into this subject, we may observe that there must be an accurate correspondence between the form of the young offspring and the bones of the mother, through which it has to be expelled. The head and anterior part of the young animal must be the larger part: but in the kangaroo, these bear no proportion to the magnitude of the parts behind: when an animal is provided for the perpendicular position, the bones called pelvis are necessarily formed of a large size to sustain the weight; and this is the case with the kangaroo. Nature has, therefore, accomplished the production of the young safely and by the simplest means,—that is, by anticipating the period of the separation of the young animal, and providing for its growth exteriorly, after it has passed through the circle of bones called the pelvis. For these reasons, we conclude that there is a relation between the mode of producing the offspring and the form of the skeleton.

I hope that I have gone far enough to prove that where there is uniformity in the shape of any part of the skeleton, it depends on the permanence of the function of the organ to which it stands related. The head and spine are, in certain respects, permanent in their forms; because the brain and spinal marrow vary only in size: but as far as regards their application

as instruments for obtaining food, for attack, or defence, they are very curiously changed in their processes and articulations, and suited to the varying uses of the parts; and we may observe that there is no change in any part of the body—whether in the spine, or the occiput, or the jaws, or the teeth, or the pelvis, or the extremities—without a corresponding adaptation extending through the whole skeleton.

IMAGINARY ANIMALS.

Archdeacon Paley expresses this opinion: "no doubt," he says, "we can imagine a greater variety of animals, than do actually exist." But what is the fact? Suppose we take as examples the fabled animals of antiquity, there is not one of these that could have existed! It may serve to show the imperfection of man's ingenuity compared with nature, and, at the same time, demonstrate the perfection of the system of the animal body, if we examine, for a moment, these imaginary animals, and enquire whether they could have fed, or breathed, or moved, or flown.

What, in fact, are these monstrous fancies, but the incongruous union of parts of different animals, which, patched together without order or system, could not have belonged to any living creature? There is no real invention here; as

when the head of a lion is joined to the belly of a goat, or the head of a woman to the body of a bird, or to the tail of a serpent. Not one of the Centaurs, the Satyrs of the Indian mountains, the Sphynxes of Egypt, the Griffins among the one-eyed nations, could have stood, run, or flown. It may be alleged, however, that these figures are but allusive representations—mystical types, of some country or element. But it is sufficient to our argument, that such as these are the only imaginary animals, which have been acquiesced in by the classical reader, as having had a fanciful existence.

When we look to the representation of the Centaur, in the antique marble, the merit of the sculptor is evinced in the attempt to reconcile our fancy to the unnatural union of the members: the expansion of the nostrils, and the coltish wildness of the expression, are indicative of the artist's design, to join the human form to that of the horse. But this could never have succeeded with one who had narrowly inspected the proportions of the horse: he would know that a fore-quarter too heavy, or a long neck and a large head, were incompatible with wind and speed, and safe going; and he would have concluded that such an animal must have foundered in the feet. What, then, would he have said to the Centaur, where an additional body, besides head and extremities, are made to rest upon the fore-feet?

The subject is classical; at least Galen takes it up, and wonders if Pindar believed in the Centaurs. "For," says he, "if such an animal were to have existence, it ought to have two mouths; one to correspond with the stomach of man, and the other to masticate for the stomach of the horse. If it could run upon the plain, it could not climb the hill, or make its way in rocky places. Though possessed of human faculties, it could not build for itself an habitation, or navigate ships and man the sails;" and more particular still in his objections, he adds, "that it could neither sit like the tailor, nor make shoes like the cobbler."

But to return to our own argument, we may observe how nature manages to rear a heavy structure at the fore part of an animal, without causing the incumbent weight to bear inordinately upon the fore-quarters, if we examine the skeleton of a Giraffe. There we see how the pressure is taken off the fore-legs, by the obliquity of the spine, and the shortness of the hind-legs. It must be confessed that, however beautiful, as works of art, the figures of the Centaur, upon antique gems, may be, they are yet monsters, and their construction a joining together of inconsistent parts.

There are few designs more difficult to execute than the representation of a Fawn or Satyr; and this results from the artist having the incon-

gruities to reconcile of uniting the human form and face to the limbs of a brute. If we have attended to the size and shape of the human extremities as compared with the upper part of the body, we may have seen the impossibility of rearing the human trunk upon the legs of a goat—that the bones were too small, and the masses of muscle displaced. The painter and the sculptor do not think of this, when they represent their Fawns dancing and piping. Yet an instant's consideration of the position of the bones, and the action of the muscles, would show them, that the limbs must have been incapable of such activity. Had such forms actually existed, they must have crept weakly on the ground.

And so of the Griffin: the eagle's wings could never have raised the body of a lion. To raise a creature on the wing, there must be a mass of muscle proportioned to the extended wing—and a surface of bone of sufficient extent to give lodgement and attachment to the muscles of flight. The bones of a lion are dense and heavy, corresponding with the muscular strength of the animal: now a skeleton composed of such bones, would never form a creature buoyant in the air. Accordingly, we see that, even if the external forms were consistent, the internal conformation would be incompatible with the existence of such an animal. The lion's tail, again, would be a very useless appendage, compared with the fine

rudder with which the eagle is enabled to direct his swoop.

These instances might be multiplied; but we venture to say that every animal form, not actually existing in nature, but the invention of the poet, would be discovered to have some defect in the balance of the exterior members, or in the relation of the parts necessary for motion; or were the exterior and moving parts duly balanced, some internal organ would be found not conformable, or displaced—too much developed, or too much compressed. In short, man's imagination is more limited than we, at first, may have believed. Our inventions are only the incongruous union of things seen in nature. It is, indeed, far beyond our power to accomplish what Paley has supposed possible; for he has said, "that multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist." This manner of viewing the subject serves only to confirm our belief in the perfection of that natural system of parts, which admits, in an infinite variety of creatures, of the changes necessary for their walking, running, flying, or swimming; and at the same time accommodates the internal functions, which minister to life, so that they are consistent with every condition of existence to which the animal may be destined.

A COMPARISON OF THE EYE WITH THE HAND.

"*And the eye cannot say unto the hand, I have no need of thee.*"

If in search of an object which shall excite the highest interest, and at the same time afford the most convincing proofs of design, we naturally turn to the Eye, as the most delicate of all the organs of the body: and this organ will suit our present purpose the better, that we have to show how much the sense of vision depends on the Hand, and how strict the analogy is between these two organs.

From the time of Sir Henry Wotton to the latest writer on light, the eye has been a subject of admiration and eulogy: but I have ventured, on a former occasion,* to say, that this admiration is misplaced, while it is given to the ball of the eye and the optic nerve exclusively. The high endowments of this organ belong to the exercise of the whole eye—to its exterior appendages, as much as to its humours and the proper nerve of vision. It is to the muscular apparatus, and to the conclusions which we are enabled to

* See Philosophical Transactions.

draw from the consciousness of muscular effort, we owe that sense which informs us of the form, magnitude, and relations of objects. One might as well imagine that he understood the effect and uses of a theodolite, by estimating the optical powers of the glasses, without looking to the quadrant, level, or plumb-line, as suppose that he had learnt the whole powers of the eye, by confining his study to the naked ball.

We must begin our observations by a minute attention to the structure and sensibility of the retina. The retina is the internal coat of the eye; it consists of a delicate, pulpy, nervous matter, which is contained between two membranes of extreme fineness, and these membranes both support it and give to its surfaces a smoothness mathematically correct. The matter of the nerve, as well as these supporting membranes, is perfectly transparent during life. In the axis of the eye, there is a small portion which remains transparent, when the rest of the membrane becomes opaque, and which has been mistaken for a foramen,* or hole in the retina. It is surprising, that with all the industry which has been employed to demonstrate the structure of the eye, it is only in the present day that a most essential part of the retina has been discovered—the membrane of Mr. Jacob. From

* It is this part which is called the foramen of Soemmerring.

observing the phenomena of vision, and especially the extreme minuteness of the image cast upon the retina, I had conceived that the whole nerve was not the seat of vision, but only one or other of its surfaces. This could not be well illustrated until this exterior membrane of the retina was demonstrated; now we see, when it is floated in water and under a magnifying glass, that this membrane is of extreme tenuity, and its smooth surface is well calculated to correspond with the exterior surface of that layer of nervous matter, which is the seat of the sense.

The term retina would imply that the nerve constituted a network: and the expressions of some of our first modern authorities would induce us to believe that they viewed its structure in this light, as corresponding with their hypothesis. But there is no fibrous texture in the matter of the nerve; although the innermost of the membranes which support the nerve, the *tunica vasculosa retinæ*, when the retina is floated and torn with the point of a needle, presents something of this appearance.

Vision is not excited by light, unless the rays penetrate through the transparent retina and reach the exterior surface from within.

It is well known, that if we press upon the eye-ball with a key or the end of a pencil-case, zones of light are produced: and they are perceived as if the rays came in a direction opposite

to the pressure. It may be said, that here the effect of the pressure is assimilated to that of light; and as light can approach and strike the part of the nerve that has been pressed from without by the key, only by entering the interior of the eye, and coming from within, the zones of light produced by the mechanical impulse, must appear in the usual direction of rays impinging upon this part: and, consequently, they will give the impression of their source being in the opposite quarter. Contrast, however, this phenomenon with the following experiment. Let the eyelids be closed, and covered with a piece of black cloth or paper, which has a small hole in it; place this hole, not opposite to the pupil, but to the white of the eye; then direct a beam of light upon the whole: now this light will be seen in its true direction. Why is there this difference in the apparent place from which the light is derived, in these two cases? Is it not because the rays, directed upon the white part of the eyeball, after penetrating the coats and striking upon the retina at this part, pierce through it, and through the humours of the eye, and impinge upon the retina again on the opposite side. This explains why the light transmitted in such a manner shall appear to come from a different quarter: but it does not explain why there should not be a double impression—why the beam of light should not in-

fluence the retina while penetrating it in the first instance, that is, in passing through it from without inwards, as well as when it has penetrated the humours and impinged upon its opposite part, from within outwards.

Another fact, which has surprised philosophers, is the insensibility of the optic nerve itself to light. If it be so contrived that the strongest beam of light shall fall upon the end of the nerve where it begins to expand into the delicate retina, at the bottom of the eye, no sensation of light will be produced. This ought not to surprise us, if I am correct in my statement, that the gross matter of the nerve is not the organ of vision, but the exterior surface of it only. In the extremity of the optic nerve there is, of course, no posterior surface; and, indeed, nothing can better prove the distinct office of the nerve itself, as contrasted with the expanded retina, than this circumstance,—that when a strong ray of light strikes into the nerve, the impression is not received. It seems to imply, that the capacity of receiving the impression, and of conveying it to the sensorium are two distinct functions.

Is not this opinion more consistent with the phenomena, than what is expressed by one of our first philosophers,—that the nerve at its extremity towards the eye, is insensible, and forms what has been called the *punctum cæcum*,

because it is not yet divided into those almost infinitely minute fibres, which he considers can alone be fine enough to be thrown into tremors by the rays of light.

Independently of this punctum cœcum, we have to observe that the whole surface of the retina is not equally sensible to light. There is a small spot, opposite to the pupil, and in the axis of the eye, which is more peculiarly sensible to visual impressions. An attempt has been made to ascertain the diameter of this spot; and it is said, that a ray, at an angle of five degrees from the optic axis, strikes exterior to this sensible part. But we shall, on the contrary, see reason to conclude, that the sensible spot is not limited to an exact circle, that it is not regularly defined, and that the sensibility, in fact, increases to the very centre.

Some have denied the existence of this extreme sensibility in the centre of the retina, attributing the distinctness of vision to the circumstance of the light being made to converge, through the influence of the humours, more correctly to this point. I shall, therefore, show how impossible it would be to have distinct vision, were not the sensibility of the retina increased gradually, from its utmost circumference to the point which forms the axis of the eye.

On looking at an object, we can see it by the rays reflected from it, even although direct light,

coming from a luminous body, may be entering the eye at the same instant. As the illumination from rays, coming thus directly to the eye, is many times stronger than that from light reflected by the object, the contrast would be so great that vision would be destroyed, if there were not this provision in the retina, by which the bright light shall fall upon a part possessing a slight degree of sensibility; while the dimmer, reflected, light falls upon the most sensible spot. If, for example, in full day, and in the open field, the eye be directed southward, the rays from the sun will enter the eye at the same time that we are looking at the objects near us: and it is perfectly clear, that if the part of the retina where the sun's rays struck, were as sensible as the spot in the centre or axis, these rays would extinguish all the secondary impressions: the glare would be painfully powerful, as when we look directly at the sun. If a momentary glance towards the sun produce a sensation so acute that we can see nothing for some time afterwards, would not the same happen, if the retina were equally sensible in all its surface, even without our turning our eyes towards it? A similar effect takes place in a chamber lighted with candles; we can not see the person who is placed immediately on the other side of the candle: for the direct light interferes with the reflected light, and effaces the slighter impression of the latter.

We perceive, therefore, that if the retina were equally sensible over its whole surface, we could not see. Let us, then, observe how we do actually see, and how the organ is exercised. There is a continual desire of exercising the sensible spot, the proper seat of vision. When an impression is made upon the retina, in that unsatisfactory degree which is the effect of its striking any part but the centre, there is an effort made to direct the axis towards it, or, in other words, to receive the rays from it upon the more sensible centre. It is this sensibility, therefore, conjoined with the action of the muscles of the eye-ball, which produces the constant searching motion of the eye; so that, in effect, from the lesser sensibility of the retina generally, arises the necessity for this exercise of the organ; and to this may be attributed its high perfections.

This faculty of searching for the object is slowly acquired in the child; and, in truth, the motions of the eye are made perfect, like those of the hand, by slow degrees. In both organs there is a compound operation:—the impression on the nerve of sense is accompanied with an effort of the will, to accommodate the muscular action to it. That the faculty of vision should be found perfect in the young of some animals from the beginning, is no more to be considered a contradiction to this, than the circumstance of the young duck running to the water the mo-

ment that the shell is broken, is to be supposed to contradict the fact, that the child learns to stand and walk, after a thousand repeated efforts.

Let us now observe how essential this searching motion of the eye is to vision. On coming into a room, we see the whole side of it, as we suppose, at once—the mirror, the pictures, the cornice, the chairs. But we are deceived; and this arises from our being unconscious of the motions of the eye: for each object in the side of the room is rapidly, but successively, presented to the most sensible spot in the eye.

It is easy to show, that if the eye were without motion, steadily fixed in the socket, vision would be quickly lost: that objects of the greatest brilliancy would be obscurely seen, or disappear, if such were the case. For example, let us fix the eye on one point—a thing somewhat difficult to do, owing to the very disposition in the eye to be constantly moving: but suppose that by repeated attempts we have at length acquired the power of directing the eye steadily on an object. When we have done so, we shall find that the whole scene becomes more and more obscure, and finally vanishes. Let us fix the eye on the corner of the frame of the principal picture in the room. At first, every thing around the frame will be distinct; in a very little time, however, the impression will become weaker, objects will appear dim, and then the eye will have an almost

incontrollable desire to wander; if this be resisted, the impressions of the figures in the picture will first fade: for a time, we shall see the gilded frame: but this also will become faint. When we have thus far ascertained the fact, if we change the direction of the eye but ever so little, the whole scene will at once be again perfect before us.

These phenomena are consequent upon the retina being subject to exhaustion. When a coloured ray of light impinges continuously on the same part of the retina, it becomes less sensible to it, but more sensible to a ray of the opposite colour. When the eye is fixed upon a point, the lights, shades and colours of objects continuing to strike upon the same relative parts of the retina, the nerve is exhausted: but when the eye shifts, there is a new exercise of the nerve: the part of the retina that was opposed to the lights, is now opposed to the shades, and what was opposed to the different colours is now opposed to other colours, and the variation in the exciting cause produces a renewed sensation. From this it appears, how essential the incessant searching motion of the eye is to the continued exercise of the organ.

Before dismissing this subject, we may give another instance. If we are looking upon an extensive prospect, and have the eye caught by an object at a distance, or when, in expectation

of a friend, we see a figure advancing on the distant road, and we endeavour to scrutinize the object, fixing the eye intently upon it, it disappears; in our disappointment we rub the eyes, cast them about, look again, and once more we see the object. The reason of this is very obvious: the retina is exhausted, but becomes recruited by looking on the other objects of different shades and colours. The sportsman on the moor or the hill side, feels this a hundred times when marking down his covey, and keeping his eye fixed, while travelling towards the spot.

Here we may interrupt our inquiry to observe how inconsistent these phenomena are with the favourite hypothesis—that light produces vision by exciting vibration in the fibres of the nerve. By all the laws of motion from which this hypothesis is borrowed, we know that if a body be set in motion, it is easily kept in motion; and that if a chord vibrate, that vibration will be kept up by a motion in the same time. It appears to me natural to suppose, that if these fibres of the nerve (which, be it remembered, are also imaginary) were moved like the chords of a musical instrument, they would be most easily continued in motion by undulations in the same time: that if the red ray oscillated or vibrated in a certain proportion of time, it would keep the fibres of the nerve in action more easily, than

a green ray, which vibrates in a different time; and if the colour of a ray depended upon the peculiar undulation or vibration, before the green ray could produce a motion corresponding with itself, it must encounter a certain opposition, in interrupting the motion already begun.*

Reverting to the sensible spot in the retina, it does not appear that we are authorised to term it a spot. The same law governs vision when we look to a fine point of a needle, or to an object in an extensive landscape. We look to the point of a pen, and we can rest the attention on the point upon the one side of the slit, to the exclusion of the other, just as we can select and intently survey a house or a tree. If the sensible spot were regularly defined, it must be very small: and we should be sensible of it;

* "Although any kind of impulse or motions regulated by any "law may be transferred from molecule to molecule in an elastic "medium, yet in the theory of light it is supposed that only such "primary impulses, as recur according to regular periodical laws, "at equal intervals of time and repeated many times in succes- "sion, can affect our organs with the sensation of light. To put "in motion the molecules of the nerves of our retina with suffi- "cient efficacy, it is necessary that the almost infinitely minute "impulse of the adjacent ethereal molecules should be often and "regularly repeated, so as to multiply and concentrate their "effect. Thus, as a great pendulum may be set in swing by a "very minute force, often applied at intervals exactly equal to "its time of oscillation, or as one elastic body can be set in vi- "bration by the vibration, of another at a distance propagated "through the air, if in exact unison, even so we may conceive the "gross fibres of the nerves of the retina to be thrown into motion

which we are not. The law, therefore, seems to be, at all times, that the nearer to the centre of the eye, the greater is the sensibility to impression; and this holds whether we are looking abroad on the country, or are microscopically intent upon objects very minute.

When men deny the fine adaptation of the muscular actions of the eye to the sensations on the retina, how do they account for the obvious fact—that the eye-ball does move in such just degrees? how is the one eye adjusted to the other with such marvellous precision? and how do the eyes move together in pursuit of an object, never failing to accompany it correctly, whether it be tracing the flight of a bird, or the course of a tennis-ball, or even of a bomb-shell? Is it not an irresistible conclusion—that to follow

" by the continual repetition of the ethereal pulses: and such only " will be thus agitated, as from their size, shape, or elasticity, " are susceptible of vibrating in times exactly equal to those at " which the impulses are repeated. Thus it is easy to conceive " how the limits of visible colour may be established: for if there " be no nervous fibres in unison with vibrations more or less " frequent than certain limits, such vibrations, though they " reach the retina, will produce no sensation. Thus, too, a single " impulse, or an irregularly repeated one, produces no light. " And thus also may the vibrations excited in the retina continue " a sensible time after the exciting cause has ceased, prolonging " the sensation of light (especially if a vivid one) for an instant " in the eye in the manner described."—Sir J. F. W. Herschel, Art. Light. Enc. Met.

Now it does appear to me that this reasoning is inconsistent with the phenomena above noticed.

an object, and adjust the action of the muscles of the eye, so as to present the axis of vision successively to it, as it changes its place, we must be sensible of these motions? for how could we direct the muscles, unless we were sensible of their action? The question then comes to be —whether being sensible of the condition of the muscles, and capable of directing them with extraordinary minuteness, the sense of the action of the muscles does not enter into our computation of the place of an object? But is not this exactly the same question recurring, as when we asked—whether in judging of the place of an object by the hand, we did not include, as a material part of the process of perception, the knowledge acquired through the sense of the muscular action of the arm? Must there not be a feeling or knowledge of the position of the hand, before we can give it direction to an object? and must we not have a conception of the relation of the muscles and of the position of the axis of the eye, before we can alter its direction to fix it upon a new object?

It surprises me to find ingenious men refusing their assent to the opinion, that the operation of the muscles of the eye is necessary to perfect vision, when they may witness the gradual acquisition of the power, by observing the awakening sense in the infant. When a bright object is withdrawn from the infant's eye, there is a

blank expression in the features; but an excitement, as soon as the object is again presented. For a time, if we shift the object before it, it is not attended with the searching action of the eye: but, by and by, the eye follows the object, and looks around for it, when lost. In this gradual acquisition of power to guide the eye to the object, there is an exact parallel to the acquisition of power to seize with the hand: in both instances, the infant seeks to join the experience obtained by means of the muscular motion, with the impression on the proper nerve of sense.

Some maintain that our idea of the position of an object is implanted in the mind, and independent of experience. We must acknowledge the possibility of this, had it been so provided. We see the young of some creatures enjoying the sense of vision perfectly at the moment of birth: but in these animals, every corresponding faculty is, in the same manner, perfect from the beginning: the dropped foal, or the lamb, rises and follows its mother. As to the property of the eye which we are considering, we must no more compare the helpless human offspring with the young of other animals, than make a comparison between man's existence and that of the fly, which has its period of life limited to an hour's duration, at noon—which breaks from its confinement, knows its mate, deposits its eggs on the appropriate tree, the willow or the thorn—

and dies. Such subjects are foreign to the enquiry; since it is obvious that the human eye has no original power of vision bestowed upon it, and that it is acquired, as the exercise of the other senses, and the faculties of the mind itself are, by repeated efforts, or experience.

If it be admitted that the ideas received through the eye, are acquired by experience, we must allow that before a conception can be formed of an object being exterior to the eye, or of its being placed in a particular direction, the mind must have been engaged in an act of comparison. Authors make the subject complex by referring to the picture drawn at the bottom of the eye, and presenting to us the mind contemplating this inverted picture, and comparing the relative position of its parts. But it is not shown how the mind looks into this camera! The question would be rendered, at least, more simple, if we asked ourselves, how we know the direction in which any single point is seen by the eye. Suppose it is a star in the heavens, or a beacon, seen by the mariner. In order to ascertain the position of the star, must he not find out some other object of comparison, some other star, which shall disclose to him the constellation, to which the one that he is examining belongs: or to ascertain the position of the beacon, must he not look to his compass and card, and so trace the relative direction of the light-

house? This is, in fact, the process followed every time that we look at an object. A single point is directly in the axis of the eye; but we cannot judge of its position, without turning to some other point, and becoming sensible of the traversing of the eye-ball and the angle to which it is moved: or if we do not see another point to compare with the first, we must judge of its place by means of a comparison with the motion of the eye itself. We are sensible that the eye is directed to the right or to the left; and we compare the visible impression on the nerve with the motion, its direction, and its extent.

Even mathematicians are found, who affirm that we judge of the direction of an object by the line in which the ray that falls upon the retina, comes to the eye. But they forget that the ray, which is here spoken of, strikes a mere point of the retina: and this point can have no direction by itself. The obliquity of the incidence of the ray cannot be estimated by means of this point alone; rays of all degrees of obliquity are converging towards it. Do not the same mathematicians in the very first lessons of their science, require as the definition of a line—that it shall be drawn through two points at least? Where are the two points at which a ray can affect the nerve, so as to indicate the direction of the line in which it approaches the eye? The cornea, or the humours of the eye, are not sensible to the

passage of the ray.* Or is this an error that has crept in from inaccurate conceptions of the anatomy? has the idea arisen from the notion that the ray passes through the thick and turbid matter of the retina, and that we can trace its course by this means?

I would ask why is there a "finder" attached to the great telescope? Is it not because this instrument magnifies in such a high degree, that the observer can only see one object, and therefore he cannot direct it in the heavens? It is to remedy this, that a smaller telescope, possessing a less power, but commanding a wider field, is mounted upon the greater one: this "finder" the astronomer directs to the constellation, and moves from star to star, until the one which he desires to examine is in the centre of the field: by which means he adjusts the larger telescope to his object. Is this not a correct illustration of the operation of the eye? The eye is imperfectly exercised when it sees but one point: it is not in the full performance of its function, unless when it moves from one point to another, judges of the degree and the direction of that motion, and thus enables us, by comparison, to form our conclusion as to the place of the object.

A most ingenious philosopher of our time, who

* See a paper by Mr. Alexander Shaw, who has explained this subject very happily.—Journal of the Royal Institution, 1832.

has opposed these views of the compound nature of the sense of vision, and maintains that the forms and relations of objects are known by the unassisted operation of the eye-ball itself—by the transmission of the rays through the humours of the eye, and by their effect upon the retina—has also affirmed, that we should know the position of objects, even if the muscles of the eye were paralytic. But I hope that it has been understood, when I attach so much importance to the motions of the eye, that I do not neglect the movements of the body, and, more especially, the motions of the hand. In truth, the measure which we take through the motions of the eye, is in correspondence with the experience obtained through the motions of the whole frame; and without such experience, we should have no knowledge of matter, or of position, or of distance, or of form. Were the eye fixed in the head, or its muscles paralytic, we should be deprived, in a great degree, of the exercise of the organ, and have lost many of the appliances necessary for its protection: but we should still be capable of comparing the visual impression with the knowledge of the movements of the body. As long as we could distinguish the right hand from the left, or must raise our head to see what is above us, or stoop to see a man's foot, we should never be at a loss to form a comparison

between the impression on the nerve of sight, and the experience of the body.

Against this view of the compound operation of the eye, it is argued:—that if a man receive the impression of a luminous body upon his eye, so that the spectrum shall remain, when the eye-lids are shut; and if he be seated upon a stool that is made to turn, and he be whirled round by the hand of a friend, without his own effort, the motion of the spectrum will correspond with his own rotatory motion. No doubt it will: because he is conscious of being turned round: a man cannot sit upon a stool that is turning, without an effort to keep his place, without a consciousness of being turned round; and being sensible, at the same time, that the impression is still before his eye, he will see the spectrum in that aspect, to which he has been revolved.

Were I not conscious that I was right, I should feel it necessary to make some apology for arguing against the opinions of eminent men, on this matter. But I conceive the explanation of the discrepancy to be, that we are influenced considerably by the different modes in which we approach the examination of such a subject. A man accustomed to observe with admiration the properties of light, and to study the effect of the humours of the eye, as an optical instrument, may be blinded to those inferences, which to me

seem undeniable, from reflecting on the living endowments that belong to the organ. When, instead of looking upon the eye as a mere camera, or show-box, with the picture inverted on the bottom, we determine the value of muscular activity ; mark the sensations attending the balancing of the body ; that fine property which we possess of adjusting the muscular frame to its various inclinations; how it is acquired in the child; how it is lost in the paralytic and drunkard ; how motion and sensation are combined in the exercise of the hand ; how the hand, by means of this sensibility, guides the finest instruments: when we consider how the eye and the hand correspond ; how the motions of the eye, combining with the impression on the retina, become the means of measuring and estimating the place, form, and distance of objects—the sign in the eye of what is known to the hand: finally, when, by attention to the motions of the eye, we are aware of their extreme minuteness, and how we are sensible to them in the finest degree—the conviction irresistibly follows, that without the power of directing the eye, (a motion holding relation to the action of the whole body) our finest organ of sense, which so largely contributes to the developement of the powers of the mind, would lie unexercised.

THE MOTION OF THE EYE CONSIDERED IN REGARD TO THE EFFECT OF SHADE AND COLOUR IN PAINTING.

A QUESTION naturally arises whether, from this part of philosophy, it be possible to suggest some principles for the assistance of the painter, in the disposition of the shades and colours of a picture. The ideas and language of the artist or amateur, when attempting to establish rules for this purpose, are certainly very vague.

We have to remark, in the first place, that the colours of objects represented in a painting, differ, in most essential circumstances, in the effect which they produce, from those of the natural objects themselves. Bodies of various colours, when placed together, in nature, have their tints reflected from each other, and so combined: this is one mode in which the hues of nature are harmonized before they reach the eye. But the colours upon the flat surface of the canvass cannot be thus reflected and mingled. Again, the hues of natural objects are affected by the atmosphere in a different manner from those in a picture: the rays proceeding from distant objects are softened by means of it;

whereas in a painting, from the canvass being close to the eye, the effect of the atmosphere will amount to nothing.

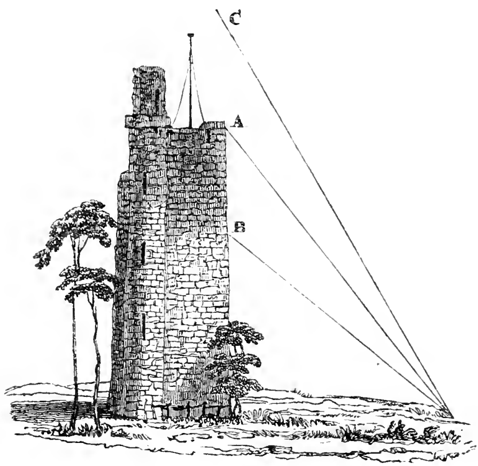
There is, however, another mode by which the eye is influenced in regard to colours, and it is an effect common to natural objects and to paintings. When we repeat the familiar experiment, of looking steadily, and for some time, upon different coloured spots, in succession, we become aware of the remarkable effect produced on the sensibility of the retina, by the impression dwelling on the nerve. As this effect is not an incidental occurrence, but is produced, more or less, whenever we exercise the eye, the nerve must be influenced, to a certain degree, in the same manner, on looking to the different colours of a picture. It is necessary, therefore, to carry this fact with us into the inquiry ; and I may offer one or two illustrations.

If we throw a silver coin upon a dark table and fix the eye upon its centre, it will be found, when we remove the coin, that there is, for a moment, a white spot in its place, which presently becomes deep black. If we put a red wafer upon a sheet of paper and continue to keep the eye fixed upon it, when we remove the wafer, the spot where it lay on the white paper, will appear green. If we look upon a green wafer, in the same manner, and remove it, the spot will be red ; if upon blue or indigo, the

paper will seem yellow. These phenomena are to be explained by considering, that the nerve is exhausted by the continuance of the impression, and becomes more apt to receive the sensation of an opposite colour. All the colours of the prism come into the eye from a surface that is white: accordingly, when we remove the coloured wafer, (take that which was red) from the white paper, all these combined colours of the prism enter: but if the nerve has been exhausted by the red colour of the wafer, it will be insensible to the red rays, when reflected from the paper; and the effect of the rays of an opposite kind will be increased: consequently, the spot will be no longer white, nor red, but of a green colour.

Let us next observe how this exhaustion of the sensibility of the nerve produces an effect in engraving; where there is no colour, and only light and shade. Is it possible that a high tower, in a cloudless sky, can be less illuminated at the top, than at the bottom? Yet if we turn to a book of engravings, where an old steeple, or tower, is represented standing up against the clear sky, we shall find that all the higher part is dark; and the effect is picturesque and pleasing. Now this is perfectly correct; for although the highest part of the tower be in the brightest illumination, it is not seen as if it were—it never appears so to the eye. The reason is, that on

looking towards the steeple, a great part of the retina is opposed to the strong light of the sky; and when we shift the eye, to look at the particular parts of the steeple, the reflected light falls upon the retina where it is exhausted by the direct light of the sky. If we look to the top of the tower, and then drop the eye to some of the lower architectural ornaments, the effect will infallibly be, that the upper half of the tower will appear dark. For example, if looking



to the point A, we drop the eye to B: the part of the tower from A to B, will be seen by that portion of the retina which was opposed to the clear sky, from A to C; and it will appear dark, not by contrast, as it might thoughtlessly be said, but by the nerve being somewhat exhausted of

its sensibility. This, then, is the first effect that we shall remark, as arising from the searching motion of the eye, and the variety in the sensibility of the nerve.

The refreshing colours of the natural landscape, are at no time so pleasing as, when reading on a journey, we turn the eye from the book to the fields and woods; the shadows are then deeper—the greens more soothing; and the whole colours are softened. Reynolds observed to Sir George Beaumont that the pictures of Rubens appeared different to him, and less brilliant, on his second visit to the continent than on his first; and the reason of the difference, he discovered to be that, on the first visit, he had taken notes, and on the second he had not. The alleged reason is quite equal to the effect; but I cannot help imagining that there is some incorrectness in the use of the term brilliant: unless warmth and depth of colouring is meant; for when the eye turns from the white paper to the painting, the reds and yellows must necessarily be deeper. If we look out from the window, and then turn towards a picture, the whole effect will be gone—the reflected rays from the picture will be too feeble to produce their impression; or if we look upon a sheet of paper, and then upon a picture, the tone will be deeper, and the warm tints stronger, but the lights and shades less distinct. If we place an

oil painting, without the frame, upon a large sheet of paper, or against a white plastered wall, it will appear offensively yellow: this is because the eye alternately, though insensibly, moves from the white paper or wall to the painting, which is of a deep tone, and consequently the browns and yellows are rendered unnaturally strong. We see the necessity of the gilt frame for such a picture, and the effect that it produces: it does not merely cut off surrounding objects, but it prepares the eye for the colours of the painting—it allows, if I may so express it, the painter to use his art more boldly, and to exaggerate the colours of nature.

Painters proceed by experiment: and in painting a portrait, they know that they can represent the features by contrasts of lights and shadows, with very little colour; but such a portrait is never popular. If they are to present the likeness without much contrast of light and shade, they must raise the features by contrasts of the colours: hence the carnations are necessarily exaggerated; but all this is softened down, by throwing a piece of drapery into the picture; and the effect of this will be so striking, from its colours preparing the eye properly for receiving those of the rest of the picture, that the features which, perhaps, before gave the idea of an inflamed countenance, will appear natural. The common resource of the painter is to throw in a

crimson curtain, or to introduce some flower, or piece of dress, that shall lead the eye, by the succession of tints, towards it: and by this means, the eye will be prepared to receive the otherwise exaggerated colours of the portrait: first surveying the red curtain, and then the countenance, the whole appears coloured with the modesty of nature.

Those who hang pictures, do not place an historical picture, painted after the manner of the Bolognese school, with distinct and abrupt coloured draperies, by the side of a landscape; for the colours of a landscape, to be at all consonant with nature, must be weak and reduced to a low tone, corresponding with the effect produced by the intervention of the atmosphere; its colours, therefore, would be destroyed by too powerful a contrast. It is because pictures are, for the most part, painted on different principles, that there is a difficulty of deciding which colours are best adapted for the walls of a gallery: but generally speaking, the dark subdued red, or morone, brings out the colours of paintings; in other words, if we look on a wall of this hue, and then turn to the picture, the prevailing green and yellow tints will appear brighter.

The word "contrast" is used without an exact comprehension of what it implies. From the illustrations that have been given, it will be seen that the effect resulting from the proper distri-

bution of colours placed together, is produced through the motion of the eye, combined with the law to which we have been adverting, of the sensibility of the retina. When we imagine that we are comparing colours, we are really experiencing the effect of the nerve being exhausted by dwelling on one colour, and becoming more susceptible of the opposite colour. In drapery, for example, there is such a mixture of different tints reflected from it, that although one prevails, the impression may be greatly modified by what the eye has previously experienced. If the colouring of the flesh be, as the painter terms it, too "warm," it may be made "cold" by rendering the eye insensible to the red and yellow rays, and more than usually susceptible of the blue and purple rays. Every coloured ray from the flesh is transmitted to the eye; but if the eye has moved from a yellow or crimson drapery, then the rays of that kind will be lost for the moment, and the colour of the flesh will appear less warm, in consequence of the prevalence of the opposite rays of colour.

It ought to be unsatisfactory to the philosophical student, to make use of a term without knowing its full meaning: yet much has been said about contrast and harmony, in painting, as resulting from the arrangement of the colours; the idea being that the colours placed together are seen at the same time, and that this

gives rise to the effect, of which we are all sensible: whereas, it results from alternately looking at the one colour and then at the other. The subject might be pleasantly pursued; but I mean only to vindicate the importance of the motions of the eye to our enjoyment of colours, whether they be those of nature or of art.

There is another subject of some interest, namely, the effect produced upon the retina when the eye is intently fixed upon an object, and is not permitted to wander from point to point. This touches on the chiaroscuro of painting; which is not merely the managing of the lights and shadows, but the preserving of the parts of a scene subordinate to the principal object. There is something unpleasant in a picture, even to the least experienced eye—where every thing is made out—where the drapery of every figure, or the carvings and ornaments, are all minutely represented: for, in nature, things are never seen in such a way. On the other hand, a picture is truly effective, and felt to be natural, when the eye is led to dwell on the principal group, or principal figure, with which it is the artist's intention to occupy the imagination. With fine mastery of his art, the painter heightens the colours of the chief parts in his picture, and subdues, by insensible degrees, those which are removed from the centre; and thus he represents the scene, as when we look intently at any

thing: that is, by making the objects which are near the axis of the eye be seen distinctly—the other objects retreating, as it were, or rising out less and less distinctly, in proportion as they recede from the centre. In the one instance, the artist paints a panorama, where, on turning round, we have the several divisions of the circle presented before the eye, and the objects visible in each appearing equally distinct; in the other, he paints a picture, which represents the objects, not as when the eye wanders from one to the other, but where it is fixed with higher interest upon some central figure, or part of the scene, and the rest falls off subordinately.

Reverting to our main argument, the proofs of beneficence in the capacities of the living frame, we look naturally to the pleasures received through this double property of the eye—its motion and sensibility; and we perceive that, whilst the varieties of light and shade are necessary to vision, the coloured rays are also, by their variety, suited to the higher exercise of this sense. They do not all equally illuminate objects; nor are they all equally agreeable to the eye. The yellow, pale green, or isabella colours, illuminate in the highest degree,* and are the

* The Astronomer selects for his telescope a glass which refracts the pale yellow light in the greatest proportion, because it illuminates in the highest degree and irritates the least.

most agreeable to the sense; and we cannot but observe, when we look out on the face of nature, whether to the country, the sea, or the sky, that these are the prevailing colours. The red ray illuminates the least, but it irritates the most; and it is this variety in the influence of these rays upon the nerve, that continues its exercise, and adds so much to our enjoyment. We have pleasure from the succession and contrast of colours, independently of that higher gratification which the mind enjoys through the influence of association.

OF EXPRESSION IN THE EYE.

In the conclusion of the volume, I took occasion to remark that natural philosophy sometimes disturbed the mind of a weak person: I recollect a student who objected to the attitude and the direction of the eyes upwards in prayer: "For," said he, "it is unmeaning; the globe on which we stand is round, and the inhabitants in every degree, or division, of the sphere, have their eyes directed differently, diverging from the earth, and concentrated to nothing." This foolish observation may lead us once more to notice the relations between the mind and the body, and external nature.

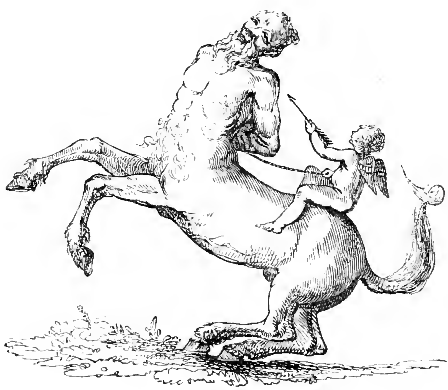
The posture, and the expression of reverence,

have been universally the same in every period of life, in all stages of society, and in every clime. On first consideration, it seems merely natural that, when pious thoughts prevail, man's countenance should be turned from things earthly, to the purer objects above. But there is a link in this relation every way worthy of attention ; the eye is raised, whether the canopy over us be shrouded in darkness, or display all the splendour of noon.

The muscles which move the eye-ball are powerfully affected in certain conditions of the mind. Independently altogether of the will, the eyes are rolled upwards during mental agony, and whilst strong emotions of reverence and piety prevail in the mind. This is a natural sign, stamped upon the human countenance, and as peculiar to man, as any thing which distinguishes him from the brute. The posture of the body follows necessarily, and forms one of those numerous traits of expression, which hold mankind in sympathy.

The same evidence that we brought forward on a somewhat similar question, regarding the expression of the hand, that is, the works of the great painters, who have made the sublimer passions of man the subjects of their art, might be adduced here ; for by the direction of the eyes, and the correspondence of feature and attitude, in their paintings, they speak to all man-

kind. Thus we must admit that the reverential posture, and the upward direction of the eyes are natural, whether in the darkened chamber, or under the vault of heaven. They result from the very constitution of the mind and body, and are too powerful to be effaced or altered. No sooner does pain or misfortune subdue a man, or move him to supplication, than the same universal expression prevails. Here is the correspondence of the mind, the frame, and external nature, by which man is directed to look for aid from above.



APPENDIX.

THE CLASSIFICATION OF ANIMALS.

IN EXPLANATION OF THE TERMS INCIDENTALLY USED IN THE VOLUME.

THE ANIMAL KINGDOM is arranged in four Divisions:

Division I. *Vertebral Animals:* so called from their possessing a vertebral column or spine.

Division II. *Molluscous Animals:* such as shell-fish, which are of a soft structure, and without a skeleton. *Etym.* mollis, soft.

Division III. *Articulated Animals:* like the worm or insect: they are without a skeleton, but their skins or coverings are divided and jointed. *Etym.* Articulus, a joint.

Division IV. *Zoophytes:* animals believed to be composed very nearly of a homogeneous pulp, which is moveable and sensible, and resembles the form of a plant. *Etym.* ζωον, *zoon*, alive; φυτον, *phyton*, a plant.

DIVISION I.

The division of vertebral animals is composed of four Classes: viz., 1. Mammalia, animals which suckle their young. *Etym.* mamma, a teat. 2. Aves. *Etym.* avis, a bird. 3. Reptilia, animals that crawl. *Etym.* from a part of the word repo, to creep. 4. Pisces. *Etym.* piscis, a fish.

The first Class, Mammalia, is divided into Orders, which are subdivided into Genera, and these are further divided into Species.

We present the principal Orders with familiar examples.

Bimana, man. *Etym.* bis, double; manus, hand.

Quadrumana. *Etym.* quatuor, four; manus, hand. Monkeys, makis or lemurs (*Etym.* lemures, ghosts). The loris tardigradus (tardus, slow; gradior, to walk) is a species of lemur.

Cheiroptera. *Etym.* χειρ, *cheir*, the hand; πτερον, *pteron*, a wing. The Bats.

Insectivora. *Etym.* insecta, insects; voro, to eat. Hedgehog; shrew; mole.

Plantigrade. *Etym.* planta, the sole of the foot; gradior, to walk. Bear; racoon.

Digitigrade. *Etym.* digitus, the toe, or finger; gradior, to walk. Lion; wolf; dog; weasel.

Amphibia. *Etym.* αμφι, *amphi*, both; βιὸς, *bios*, life. Walrus; seal.

Marsupialia. *Etym.* marsupium, a pouch. Kangaroo; opossum.

Rodentia. *Etym.* rodo, to gnaw. Squirrel; beaver; rat; hare.

Edentata. *Etym.* edentatus, toothless: animals without the front teeth. Ai; unau; armadillo; ant-eater; tamandua; megatherium (μεγα, *mega*, great; θηριον, *therion*, a wild beast); megalonyx (μεγας, *megas*, great; ονυξ, *onyx*, a claw); ornithorhynchus (ορνιθος, *ornithos*, of a bird; ῥυγχος, *rhynchos*, a beak.)

Pachydermata. *Etym.* παχυς, *pachys*, thick; δερμα, *derma*, skin. Rhinoceros; elephant; mammoth; mastodon (μαστος, *mastos*, a nipple; οδων, *odon*, a tooth.) Anoplетherium (ανοπλος, unarmed, θηριον). Palæotherium (παλαιος, ancient, θηριον) tapir: solidungula (solida, solid; ungula, the hoof) as the horse, couagga.

Ruminantia. *Etym.* rumino, chew the cud. Camel; giraffe; deer; goat; cow; sheep.

Cetacea. *Etym.* cetus, a whale. Dolphin; whale; dugong.

Second Class. *Aves*, or *Birds*.

Accipitres. *Etym.* accipiter, a hawk. Vulture; eagle; owl.

Passeres. *Etym.* passer, a sparrow. Lark; thrush; swallow; crow; wren.

Scansores. *Etym.* scando, to climb. Parrot; wood-pecker; toucan.

Gallinæ. *Etym.* gallina, a hen. Peacock; pheasant; pigeon.

Grallæ. *Etym.* grallæ, stilts. Ostrich; stork; ibis; flamingo.

Palmipedes. *Etym.* palma, the palm of the hand; pes, foot. Swan; pelican; gull.

THIRD CLASS. *Reptiles.*

Chelonia. *Etym.* χελυς, *chelys*, a tortoise. Tortoise; turtle.

Sauria. *Etym.* σαυρα, *saura*, a lizard. Crocodile; alligator; chameleon; dragon; pterodactyle (πτερον, *pteron*, a wing; δακτυλος, *dactylus*, a finger); ichthyosaurus (ιχθυς, *ichthys*, a fish; σαυρα, *saura*, a lizard); plesiosaurus (πλησιον, *plesion*, near to; σαυρα, *saura*, a lizard); megalasaurus (μεγαλη, *megale*, great; σαυρα, *saura*, a lizard); iguanadon; hylæosaurus (ὑλη, wood, σαυρα).

Ophidia. *Etym.* οφις, *ophis*, a serpent. Boa; viper.

Batrachia. *Etym.* βατραχος, *batrachos*, a frog. Frog; salamander; proteus.

FOURTH CLASS. *Fishes.*

Chondropterygii. *Etym.* χονδρος, *chondros*, gristle; πτερυξ, *pteryx*, a fin. Ray; sturgeon; shark; lamprey; ammocete (αμμος, *ammos*, sand; κητος, *cetos*, a fish.)

Plectognathi. *Etym.* πλεκω, *pleco*, to join; γναθος, *gnathos*, the jaw. Sun-fish; trunk-fish.

Lophobranchi. *Etym.* λοφος, *lophos*, a crest; βραγχια, *branchia*, the gills. Pipe-fish; pegasus.

Melacopterygii. *Etym.* μαλακος, *malakos*, soft; πτερυξ, *pteryx*, a fin. Salmon; trout; cod; herring; remora.

Acanthopterygii. *Etym.* ακανθα, *acantha*, a thorn; πτερυξ, *pteryx*, a fin. Perch; sword-fish; mackarel; lophius piscatorius (λοφια, *lophia*, a pennant; piscator, a fisher); chætodon rostratus (χαιτη, *chæte*, hair; οδων, *odon*, a tooth; rostratus, beaked); zeus ciliaris (cilium, an eyelash.)

DIVISION II.

MOLLUSCOUS ANIMALS.

1st Class. Cephalopoda. *Etym.* κεφαλη, *cephale*, the head; ποδα, *poda*, the feet. Animals which have their organs of motion arranged round their head.

This Class includes Sepia, or Cuttle-fish. Argonauts (Αργω, the ship Argo, ναυτης, *nautes*, a sailor). Nautilus, (ναυτης, *nautes*, a sailor). Ammonite, an extinct Cephalopode which inhabited a shell resembling that of the Nautilus; coiled like the horns of a ram or of the statues of Jupiter Ammon; whence the name. Belemnites: also extinct: the shell is long, straight, and conical (βελεμνον, *belemnon*, a dart). Nummulites: likewise extinct. Whole chains of rocks are formed of its shells. The pyramids of Egypt are built of these rocks, (nummus, a coin, λιθος, a stone).

2nd Class. Pteropoda. *Etym.* πτερον, *pteron*, a wing; ποδα, *poda*, feet; having fins or processes resembling wings on each side of the mouth.

The Clio Borealis, which abounds in the North Seas, and is the principal food of the whale.

3rd Class. Gasteropoda. *Etym.* γαστηρ, *gaster*, the belly; ποδα, *poda*, the feet. Animals which move by means of a fleshy apparatus placed under the belly.

The snail; slug; limpet.

4th Class. Acephala. *Etym.* α, *a*, without; κεφαλη, *cephale*, the head. Molluscous animals without a head.

The oyster; muscle.

5th Class. Brachiopoda. *Etym.* βραχιων, *brachion*, the arm; ποδα, *poda*, the feet. Animals which move by means of processes like arms.

Lingula; terebratula.

6th Class. Cirrhopoda. *Etym.* cirrus, a lock or tuft of hair; ποδα, *poda*, the feet.

Balanus; barnacle anatifera, (anas, a duck, fero, to bring forth).

DIVISION III.

ARTICULATA.

1st Class. Annelides, or Vermes. *Etym. Annellus*, a little ring; *vermis*, a worm.

Leech; sea-mouse; earth-worm; sand-worm; tubicolæ, (tubus, a tube, colo, to inhabit); worms which cover themselves by means of a slimy secretion that exudes from their surfaces, with a case of small shells and pebbles, like the caddis-worm, or with sand and mud.

2nd Class. Crustacea. Animals which have a shelly crust, covering their bodies.

The crabs; shrimps; lobsters.

3rd Class. Arachnida. *Etym. αραχνης, arachnes*, a spider.

Spiders; aranea scenica, or saltica; the leaping spider; the scorpion spider; the mite.

4th Class. Insecta. They are divided into insects which are without wings and those which have them: and these are further subdivided according to the peculiarities of the wings.

Aptera (*α, a*, without; *πτερον, pteron*, a wing). Centipede (having a hundred feet); louse; flea.

Coleoptera (*κολεος, coleos*, a sheath or scabbard, *πτερον*, a wing), insects which have their wings protected by a cover, as the beetle, corn-weevil. *Orthoptera* (*ορθον, orthon*, straight, *πτερον*), as the locust, grass-hopper. *Hemiptera* (*ἡμισυ, hemisu*, half, *πτερον*), insects which have one half of their wings thick and coriaceous, and the other membranous; such as a bug, tick, fire-fly. *Neuroptera* (*νευρον, neuron*, a nerve, *πτερον*), dragon-fly; ant-lion; ephemera (*επι τῆμερα*, a day). *Hymenoptera* (*ὑμεν, hymen*, a membrane, *πτερον*), the bee; wasp; ant. *Lepidoptera* (*λεπις, lepis*, a scale, *πτερον*), moth; butter-fly. *Rhipiptera* (*ῥιπις, ripis*, a fan, *πτερον*), xenos; stylops. *Diptera* (*δις, dis*, double, *πτερον*), house-fly; gnat.

DIVISION IV.

ZOOPHYTES.

Echinodermata (*Etym.* εχινος, *echinos*, a hedgehog; δερμα, *derma*, the skin), the star-fish; sea urchin. *Entozoa* (εντος, *entos*, within; ζωον, a living thing), tænia; hydatid. *Acalephæ* (ακαληφη, *acalephe*, a nettle), medusa; polypi; sea-anemone; hydra; tubipora (inhabiting tubes); sertularia; cellularia; flustra; coralline, sponge. *Infusoria* (found in infusions or stagnant water), monas; vibrio; proteus.

THE END.

C. WHITTINGHAM, TOOKS COURT, CHANCERY LANE.